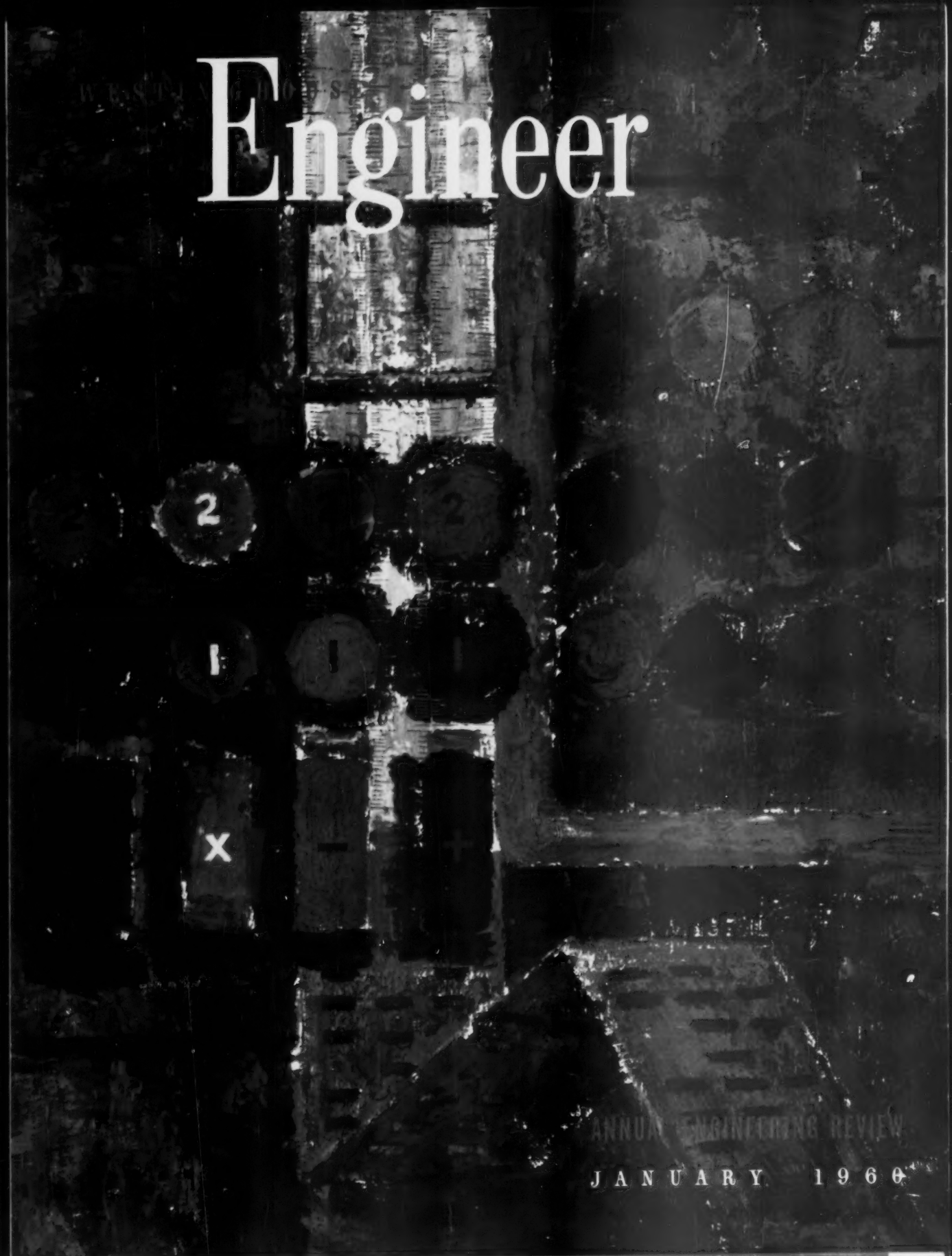
# Engineer



ANNUAL ENGINEERING REVIEW

JANUARY 1960

## Behind this issue . . .

An annual issue reviewing research and engineering progress is a tradition of long standing at Westinghouse, predating even the Westinghouse ENGINEER. As in previous issues, the subjects in this review cover a wide breadth of interest, from nuclear reactors to tiny semiconductor rectifiers, and a broad range of industrial applications.

We have often referred to this review as a "cross section" or "sampling" of significant developments at Westinghouse, and it is literally that. Perhaps the best indication of this is the manner in which the issue is assembled.

The first step in preparing this issue occurred when the editors asked the various department and division engineering managers of Westinghouse to submit a selective list of recommendations of important developments in their respective organizations that should be reported. This produced a total list of over 500 different subjects. From this point on, throughout the entire editorial period, the editors go through a repetitive cycle of gathering information, cutting, combining, writing and rewriting to reduce the 500 subjects to a usable number. All told, they frequently write about 200 stories, some of which are combined with others, many of which are eventually eliminated. Thus the final issue contains about 80 separate stories, and in these stories about 150 of the original suggested subjects (plus some new ones) are covered.

Because any review such as this must be limited in scope, we hope you will bear in mind that we use the word "sampling" advisedly, that the subjects discussed here are but a small representative part of a much greater development effort. We hope that in this sample you will find subjects of interest and potential usefulness.

J. A. HUTCHESON
*Vice President, Engineering*

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COVER DESIGN: Computing devices are the subject of this issue's cover design. An abacus, slide rule, computer keyboard, and punched tape were chosen by cover artist Dick Marsh for his symbolization.


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Published bimonthly (January, March, May, July, September, and November) by Westinghouse Electric Corporation, Pittsburgh, Pa.

SUBSCRIPTIONS: Annual subscription price in the United States and possessions is $2.50; in Canada, $3.00; other countries, $3.00. Single copy, 50¢. Address all communications to *Westinghouse* ENGINEER, P.O. Box 2278, 3 Gateway Center, Pittsburgh 30, Pa.

INDEXING AND MICROFILM: Westinghouse ENGINEER contents are regularly indexed in Industrial Arts Index. Reproductions of the magazine by years are available on positive microfilm from University Microfilms, 313 N. First Street, Ann Arbor, Michigan.

THE WESTINGHOUSE ENGINEER IS PRINTED IN THE UNITED STATES BY THE LAKESIDE PRESS, CHICAGO, ILLINOIS



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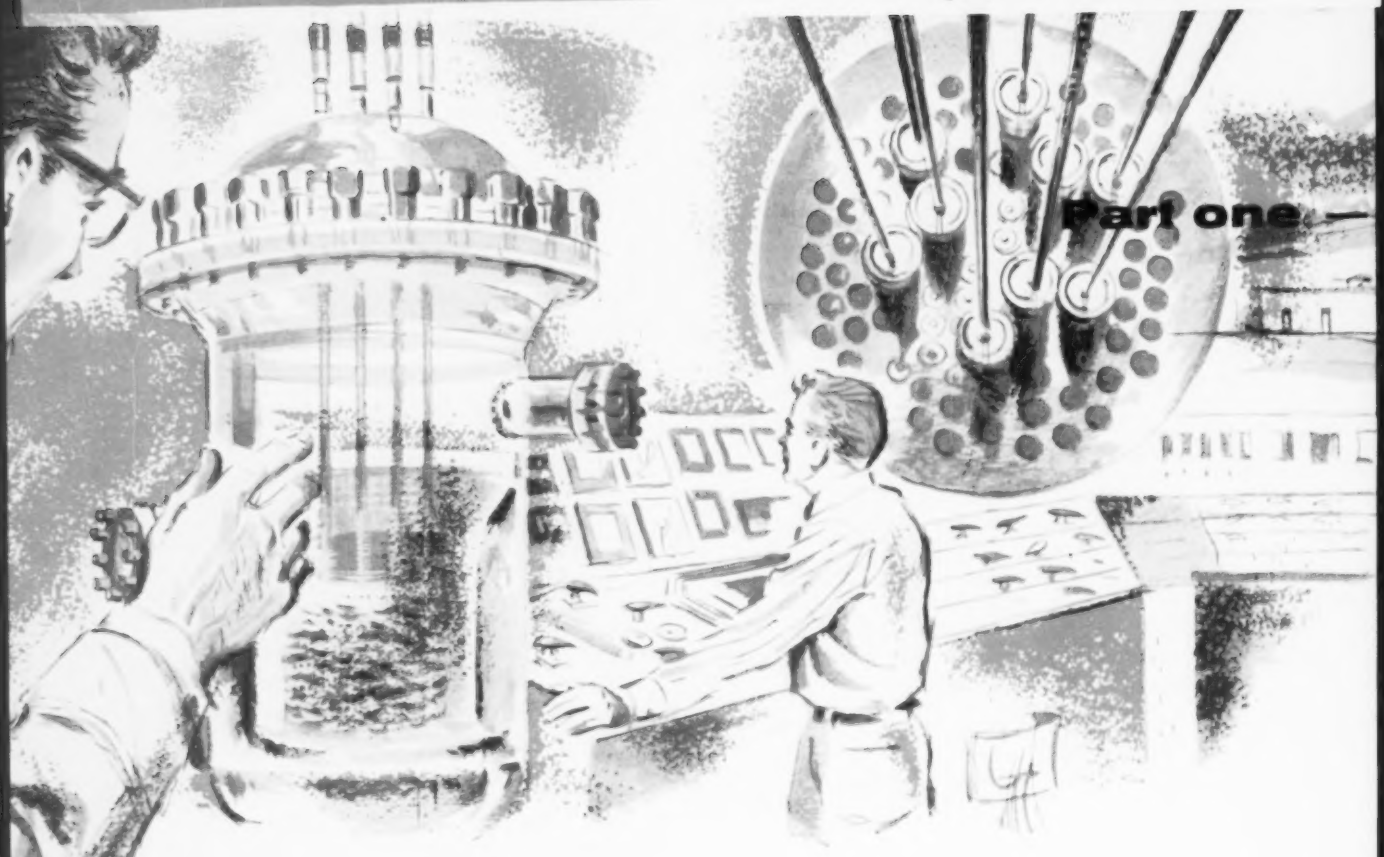
Volume Twenty, Number One, January 1960

Westinghouse ENGINEER




## economic power from the atom

In considering the economics of adding a nuclear power plant to their systems, electric utilities have faced a large number of unknowns, simply because the nuclear art is still young, and many technical and economic questions have yet to be answered. There are, for example, many different reactor types, each with its own set of variables; and there are many different geographic locations for generating plants, each with its own peculiar set of economics. On top of this, there are many business questions, involving such things as methods of accounting and financing.

Despite the many factors involved, however, substantial progress is being made toward obtaining black and white answers to the questions. For example, recently Westinghouse, in cooperation with architectural and engineering firms, has completed one phase of a continuing study of reactor types, and gained some significant facts. The study identified three different nuclear power plant projects as logical "next steps" for utility companies to undertake. Of particular significance is the fact that in two of these projects, plant output, overall plant costs, and fuel life can be guaranteed.

The three plants are: (1) a 330-mw closed-cycle light water plant; (2) a 225-mw plant, utilizing a nuclear reactor plus fossil-fired superheating; and (3) a 20-mw integral boiling and superheating reactor, in which water would be both boiled and then superheated within the same reactor core. The first two of these plants can have the guaranteed factors indicated above. The third would be a prototype, leading to the ultimate construction of a larger plant of about 200-mw output.

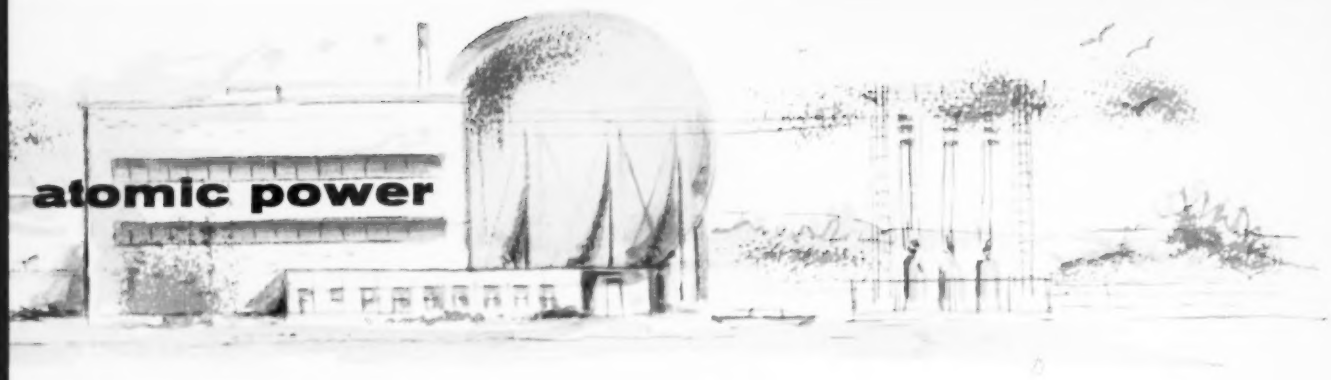
These are by no means the only promising reactor types for the future. Many types are being analyzed by Westinghouse, and of these, many have great potential for the long-range future. Moreover, the day will probably never come when one reactor type will be best for all sizes and geographical locations. However, the studies indicate that these three are good programs for immediate consideration by utilities, and, in the case of the two large plants, have the best possibilities for economic operation when completed. The smaller 20-mw plant, as a prototype, would not produce economic power, but has great promise for the longer range future.

*330-Mw Reactor Plant*—The closed-cycle reactor is the reactor type about which most is known today. One prime factor in considering this type of plant is the fact that its economics are particularly attractive in the large plant sizes required in today's utility plants. Studies revealed that power costs decreased steadily with increased rating of closed-cycle plants up to 330 mw, and then leveled off; the reason for the leveling was not nuclear, but because beyond this point parallel turbines would be required—an additional capital expense.

The 330-mw plant can produce economical electric power in the higher fuel cost areas of the United States.

*225-Mw Reactor Plant*—The second of the proposed plants is a water reactor designed to have nuclear heating and fossil-fired superheating. A superheater using nuclear fuel could be designed, but at the present stage of development the problems involved would add substantially to cost.

In this "combination" plant, water would be circulated through the reactor and would boil at 2115 psi. The




steam-water mixture would then pass through a steam drum where the steam would be separated and passed on to the superheater. Steam coming from the superheater would be at 1800 psi and 1000 degrees F. The total heat rate from this plant would be 9040 Btu per kwhr—the best obtained from a nuclear plant to date. This plant could be built immediately, and could be in operation four years from the start of the project.

The total power cost from this plant would be similar to the 330-mw plant.

*20-Mw Prototype Plant*—A logical step following the combination plant is an all-nuclear plant with integral super-heating. In the design recommended, both heating and superheating would be accomplished within the reactor core; i.e., no separate superheater would be required. Water would be passed through pressure tubes in the reactor, would boil, and then be circulated to a steam drum. Separated steam then would be passed through superheating tubes in the perimeter area of the core, then collected in a header, and passed to the turbine.

Although the problems involved in this reactor are sufficient to necessitate a prototype plant, the research and development effort largely involves refinement of techniques, and operating experience with the prototype system.

All three of these plants are thoroughly feasible today. Significantly, two of the three can be built in large sizes today, and can provide economic power from the atom in some areas. As fossil fuel costs go up, these nuclear plants will become increasingly competitive. ■

## project progress

During 1959, progress with two atomic power plants moved into late stages of construction; another moved into advanced stages of research and development; and two other projects were in early engineering stages.

The BR-3 reactor plant, a 11.5 electrical megawatt system for the Centre D'Etudes de L'Energie Nucleaire at Mol, Belgium, is expected to go critical in mid-1960. Essentially, all major components except the control panel and the reactor core are at the construction site. A full-scale criticality experiment was undertaken during the last few months of 1959 at the Westinghouse Reactor Evaluation Center, with the core shipment to follow completion of tests.

Construction of the Yankee Atomic Electric Plant at Rowe, Massachusetts is only one step behind the Belgian plant. Construction at the site was about two-thirds complete by the end of 1959 and essentially all major components with the exception of the reactor vessel had been delivered. The design of the Yankee core is now completed and fabrication of fuel rods is underway; the first fuel assemblies were shipped to the construction site late in October. Hydrostatic tests of the Yankee plant primary system are scheduled for mid-1960, and the plant will go critical in late 1960.

In much earlier stages is the prototype pressure-tube reactor for the Carolina-Virginia Nuclear Power Associates. This reactor will produce 17-mw electrical output and will serve as a prototype for a 200-megawatt reactor. A reference design for this plant was completed during 1959, which enabled engineers to start on detailed engineering design for the prototype plant. The plant is scheduled to go critical in mid-1962, thus construction work at the site will be started in the early part of 1960.

The Enrico Fermi nuclear plant in Italy, being built for the Societa Elettro-nuclear Italiana (SELNI), will in many respects be similar to the Yankee plant. However, this will be a larger plant, in terms of electrical output, being rated at 165-mw net electrical output. The major difference will be in the core, which will have multi-region loading in contrast to the uniform loading of the Yankee core. Specifications for the long-lead-time equipment, such as the reactor vessel, main coolant pumps, and steam generators have been prepared, design parameters calculated for the core, and requirements for other equipment established during 1959. The Selni plant is scheduled to go critical in 1963.

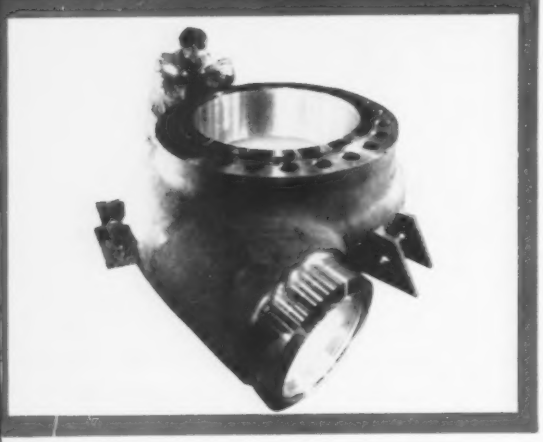
A new project initiated during 1959 was a 5000-kw nuclear reactor for the General Public Utilities system. This unit will be installed at an existing power station in Saxton, Pennsylvania and will feed steam to a turbine generator in this plant. The reactor itself will have a heat rating of 20 megawatts.

The plant is a joint undertaking of Westinghouse, General Public Utilities, and Gilbert Associates, Inc. Site construction is scheduled to be started in early 1960, and major components delivered starting in March 1961. The plant is scheduled for completion, ready for installation of the core in early 1962.

Research and development efforts will include studies directed toward increasing the useful life and heat generating capacity of various nuclear core designs. The phenomena associated with pressurized and boiling water will also be investigated over a wide operating pressure—from 500 to 2000 psi. ■

## outer space and nuclear power

When space flight gets into the stage where extensive exploration is possible, a nuclear power plant of



**Top**—This new twin-loop test facility is designed to test canned motor-pumps, including a full range of sizes up to those that can handle 22 000 gallons per minute. Tests on various sizes can be made without changing the basic configuration of the loop.

**Bottom**—This 16 000-pound canned motor-pump volute is being made for the Yankee Atomic Electric Company's nuclear power plant. The technician is checking dimensions on the threads for bolts that will hold the upper portion of the pump in position. The finished canned motor-pump will be over 11 feet high, and will be rated at 1600 hp.

some form seems a virtual necessity. As of now, there seems to be no other form of energy that will provide the long-life power requirements, and that can be built within a reasonable timescale. In recognition of this, Westinghouse last year established a new organization, called the Astronuclear Laboratory, with the purpose of developing nuclear energy for outer space application.

As compared to terrestrial nuclear power plants, a space reactor system will have several basic differences. One, it will have to be much lighter per unit of power output than its earth-bound relative—by a factor of at least ten times. Two, the unit will have to operate at much higher temperatures. This is necessitated by the fact that heat radiation is more difficult in space, and that radiation efficiency increases as about the fourth power of temperature. A third basic difference will lie in the degree of automatic control required in the space reactor.

As in the case of more conventional nuclear plants, the most serious obstacle will be the development of the necessary materials, particularly in view of the high temperature operation of the reactor system. Therefore, one of the focal points of the new Astronuclear Laboratory will be materials development. ■

## first refueling of PWR

The pioneering Shippingport Nuclear Power Plant was shut down for refueling in early Autumn after piling up an impressive performance since the reactor first went to full power in December 1957. A vast amount of information has been gained from the operation of this plant, all of which will be useful in future reactor design and operation.

During its operation, the Shippingport core has logged over 5800 effective full power hours, or in excess of 2800 hours more than its original design lifetime. The plant operated at full power approximately three-fourths of the seed lifetime. One full power run of more than 1000 hours was completed without interruption. For several weeks during May, June and July, the plant operated as a peak load unit of the Duquesne Light Company system while other units were out of service for maintenance or because the system needed Shippingport capacity.

Only the seed elements in the seed-and-blanket arrangement of the core are being replaced at this refueling since the blanket elements are not significantly expended. Seed elements are being replaced by flooding the fuel canal and performing the refueling under water. The reactor head was not removed. Expended elements are being removed and new elements inserted through fuel ports using a specially-designed fuel handling tool, which is inserted through the fuel port and indexed to move to the proper fuel location; the tool then "grasps" the individual element and removes it through the port.

At the time the seed elements are replaced, a hafnium control rod will be replaced by a new hafnium rod. The replaced rod will then be exhaustively tested and analyzed.

This second seed will be only slightly different from the first. In order to increase the expected lifetime, a greater quantity of highly-enriched uranium will be used and will contain a burnable poison, boron. ■

## naval reactors program

*Large Ship Prototype Goes to Full Power*—The two power plants of the land-based prototype for a large ship nuclear plant (called A1W) produced full power at the Naval Reactor Facility in Idaho during 1959. The first of the two reactors achieved full power in January 1959, the second reactor in October, 1959.

The A1W Test Facility serves as a land-based prototype of a nuclear power plant suitable for driving one shaft of a large naval surface ship, such as an aircraft carrier or cruiser. The two reactors are located in a simulated ship's hull, which duplicates a portion of the machinery spaces of a large nuclear-powered attack aircraft carrier. Associated with the reactor plants is a propulsion plant, which includes the propulsion turbine and related auxiliary systems and controls.

The prototype has several principal missions. It will permit verification of machinery arrangement within the hull; will permit full-scale testing of the reactor and propulsion plants and their associated controls and auxiliaries; furnish design data for future plants; provide a training facility for Navy personnel; and verify the operation of two reactors working in parallel and supplying a single turbine with steam. This is the first attempt at controlling the heat output of two reactors working in parallel to supply a common steam plant.

In addition, Westinghouse, in technical cooperation with and under the direction of the Naval Reactors Branch, USAEC, is designing and developing the power plants for two nuclear powered surface ships, which will utilize

A1W type reactors. These ships are the cruiser, *Long Beach*, CG(N)9, the first nuclear-powered surface ship, which was launched in July 1959, and the aircraft carrier *Enterprise*, CVA(N)65, to be launched in 1960.

*Submarine Fleet Grows*—The number of nuclear-powered submarines in service continues to mount. In addition to the four submarines commissioned prior to 1959 with Westinghouse designed nuclear reactors—the *Nautilus*, *Skate*, *Swordfish*, and *Sargo*—four others were completed or underwent sea trials during the past year.

In March, the *Skipjack*, the first of a radically new class of submarines, attained the highest speed ever attained by a submarine. The *Skipjack* was commissioned in April, and joined the fleet.

Also tested at sea during 1959 were: the *Seadragon*, a fleet-type submarine, and the *Halibut*.

In addition to these submarines, three others were launched—the *Theodore Roosevelt*, the *George Washington*, and the *Patrick Henry*, all ballistic-missile firing submarines.

Meanwhile, the first nuclear submarine, the *Nautilus*, entered a shipyard for its second refueling since it began operation in early 1955. ■

## magnetic jack—operation bootstrap

Reactor control rods must be sealed within the reactor system they control. Rods that penetrated the pressure boundary would have to depend on shaft seals, gaskets, or packing, all of which are not dependable enough for such purposes in a nuclear system. A new magnetic jack system positions the control rods accurately and quickly; in many applications it can be used to supplant more complicated and expensive systems.

Basically the system consists of a series of dc operating coils, located outside the pressure thimble in which the rods move; magnetic flux passing through the walls of the thimble controls the operation of grippers that hold the control rod. In a simplified way, the operation works something like this: One set of stationary grippers normally holds control rods in any given position. If rods are to be withdrawn, a second set of movable grippers is energized. These, like the stationary grippers, are holding devices, but can move $\frac{1}{8}$ inch along the axis of the control rod. Once the movable grippers are energized, the stationary grippers are de-energized. At this point another coil—a lift coil—comes into play. By induced magnetic field it lifts the movable gripper—and thus the control rod—$\frac{1}{8}$ inch upward. At this point the stationary gripper is again energized to hold the rod in its new position, and the movable grippers de-energized and returned to their original position. This cycle is then repeated at a rate of 85 steps per minute to withdraw a control rod at 0 to 11 inches per minute. If a "scram" is necessary, all circuits are interrupted, and the mechanism releases the control rod for a free fall into the core.

Actual rod position is measured by a stack of indicator coils surrounding the upper portion of the pressure housing; these create a differential transformer with the drive rods as a core. Connections allow voltage readout at close intervals for fine position indication, or across the entire coil stack in series for a coarse indication.

The magnetic grip of this system, plus the fact that it has but one moving part, means that the control has extremely long life and a high degree of reliability. At present the system is applicable to control rods weighing up to 1000 pounds, and to pressurized-water reactors up to 134-mw electrical output. ■

## hot lab expands

The effects of intense nuclear radiations on materials and structures cannot be accurately predicted for new materials or combinations of materials. As a result, engineers must depend to a large degree on irradiation of samples and subsequent examination and physical testing in hot laboratories.

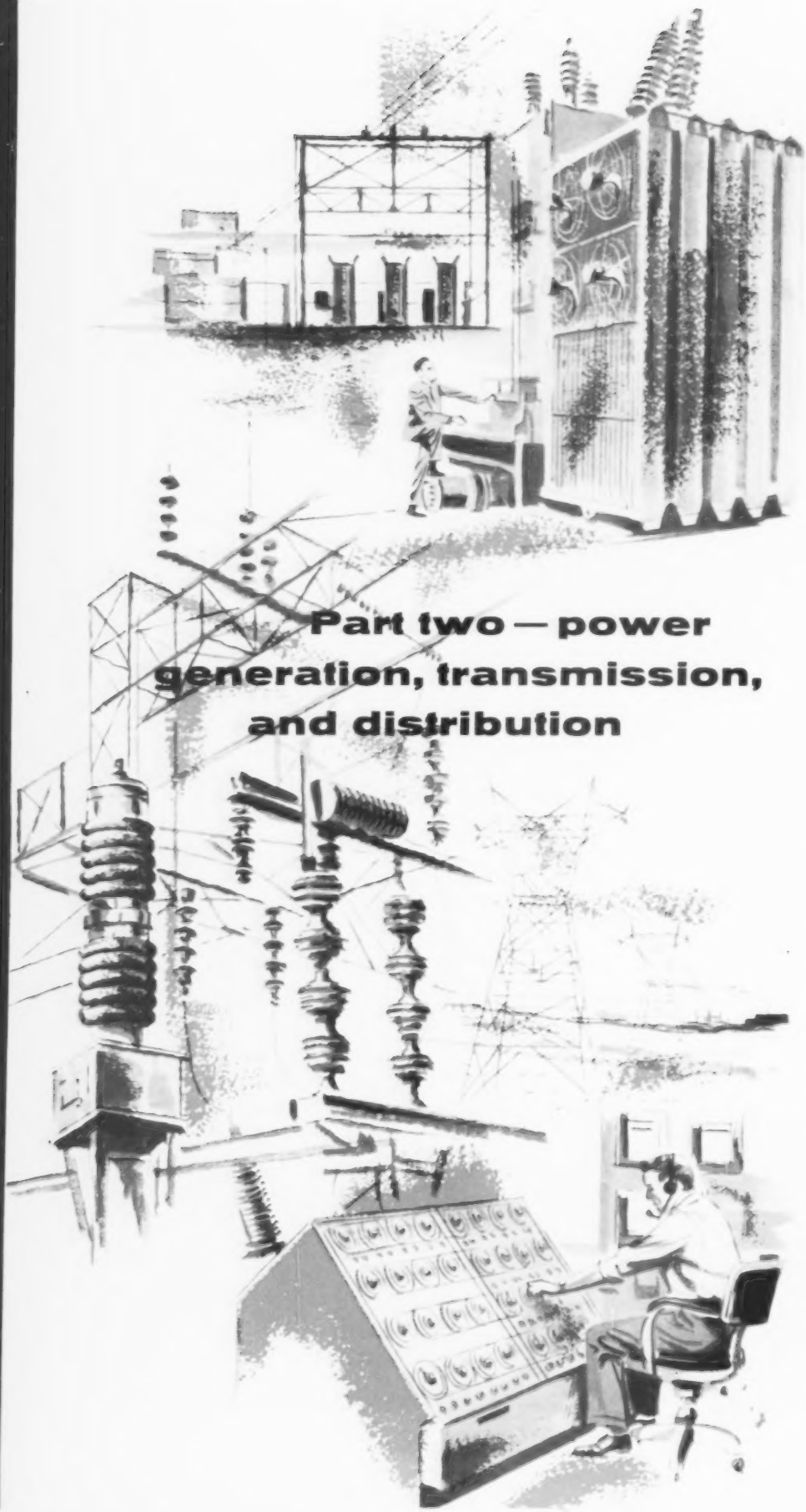
As the scope of reactor technology increases, the need for knowledge about irradiation effects increases, and the facilities for examining and testing irradiated materials must increase accordingly. At the Bettis Atomic Power Laboratory, the hot laboratory is now undergoing a series of major expansions, which will more than double the facilities available.

Before the expansion, the hot laboratory consisted of eight high-level cells, a steel cell for metallography, and supporting facilities, such as storage pits, decontamination areas, and waste-handling areas.

Included in the expansion are eight new high-level cells, two new metallography cells, space for an x-ray diffraction unit, an analytical chemistry area, and support facilities.

Also to be built in the near future is an alpha-active material facility, for radiochemistry on fuels in which the level of plutonium is high enough to warrant special precautions. ■

The land-based prototype nuclear power plant for the Navy's large surface ships. In the foreground is the cooling tower for cooling water used in the A1W plant circulating system. Behind it is the building that houses the two-reactor propulsion plant. This A1W plant is located at the Naval Reactors Facility at the Atomic Energy Commission's testing station in Idaho.



# Part two — power generation, transmission, and distribution

## TURBINES AND GENERATORS

### steam turbine developments

As electric utility systems grow, larger steam turbine sizes become inevitable. With this fact in mind, Westinghouse turbine designers embarked three years ago on an advance development program for turbine components and associated equipment. Using experience available in turbine design and operation, and factoring in expected industry trends, engineers are "pre-engineering" a complete line of turbine elements. When completed, these elements can be used in arrangements ranging from a tandem-compound double-flow unit to a double-shaft cross-compound octuple-flow unit.

Westinghouse is now in a position to design and build an 800-mw turbine generator by a logical arrangement of these newly developed components. In the past, such an accomplishment would have required a completely new "custom-engineered" machine. Today, most of these components or building blocks are already designed, and many are being built for turbine generators presently under construction. This 800-mw unit is designed for operation with 2400-psi inlet steam pressure. The same basic design could be extended to higher ratings with higher inlet steam pressures.

Turbine designers consider the advance element design program a major addition to development programs on metallurgy, thermodynamics, and mechanical design features. These pre-engineered components will permit arrangements to accommodate the wide range of turbine applications expected to meet the industry needs.

*Low-Pressure Blading*—The pre-engineered turbine elements incorporate a number of technical advances. One major accomplishment is a new design of 3600-rpm low-pressure turbine exhaust blading that uses 23-, 25-, and 28-inch long blades. The 23- and 25-inch exhaust blades are an improved thermodynamic design of previous blades of the same length. The 28-inch blade is a completely new design, extending turbine capacities. Field tests of the new blade design have confirmed the substantial gains indicated by laboratory model tests. Together with the blading improvements, changes have been made to the low-pressure turbine exhaust configu-

ration. These changes have resulted in further improvement in turbine performance.

The first application of the new 28-inch blade will be in a 342-mw, cross-compound, steam turbine generator for the Public Service Electric and Gas Company of New Jersey. Scheduled for operation in 1962, the machine will be installed in the company's Sewaren Generating Station. The turbine will use four rows of 28-inch-long last row blades, giving the largest exhaust annulus area of any quadruple-flow 3600-rpm turbine.

The increased centrifugal stresses in the longer turbine blades, such as the 25- and 28-inch 3600-rpm exhaust blades, required the use of a material with higher yield strength. A 12 percent chrome steel with additional alloying elements was selected. This material, when heat-treated, develops the required strength and has many other desirable properties, such as ductility, corrosion resistance, higher fatigue strength, and suitability for brazing of stellite erosion shields. The method used for welding the lashings after assembly of standard 12 percent chrome blading was not applicable to this new material. A new bimetallic construction was developed to permit this welding. A standard 12 percent chrome tip is flash welded (under heat and pressure) to each lashing projection. The blade and lashing tip assembly is then heat-treated to restore the superior properties of the new blade material, and retain weldability of the lashing tip. ■

## 22 000-kilowatt gas turbine for "peak shaving"

The concept of using gas turbines for electric utility peaking service—supplying power for short periods when electrical system loads are unusually high—has been proven by Westinghouse through many years of service of small size standard gas turbine units, both here and abroad, ranging in capacity up to 5000 kw. However, a 22 000-kw gas turbine now being manufactured for the Philadelphia Electric Company is one of the first gas turbine generator combinations specifically designed for this service.

This 22 000-kw unit will incorporate many unusual features of gas turbine generator design. The gas turbine will employ complete rotor and stator cooling. The generator will employ a completely forced-air cooled rotor.

Previously, the innercooling principle has been used only on large main generator machines. The use of innercooling permits rotor size reduction and minimizes winding stresses. These cooling features on both the gas turbine and generator are of prime importance in providing the requirements for an integrated "peak shaving" plant designed specifically to meet the growing needs of the utility industry. ■

## flash evaporating make-up water

The flash evaporator, first applied in Kuwait, Arabia for producing pure water from sea water, is moving into a new area—supplying ultra-pure boiler-feed water for steam turbines.

The new application can be classified into two groups: First a single-stage evaporator can be built into the regenerative steam cycle to evaporate make-up water; or second, a multistage unit can be installed independent of the steam cycle for supplying water to the cycle. The latter method particularly applies to plants already installed, which are now on peaking service. The second version is also applicable for industrial plants where there is a particularly large make-up water requirement.

Flash distillation offers particular promise where the available water has high impurity content, such as sea water. Extremely high-purity water can be supplied more economically than with the previously used submerged tube-type evaporators or demineralizers.

The first multistage flash evaporator for supplying boiler-feed water is now being built for the Philadelphia Electric Company. The unit will be a 144 000-gallon per day, 12-stage unit to supplement submerged-tube evaporators. The first single-stage flash evaporator built into the regenerative steam cycle has been sold to New England Power Company for the new Brayton Point Station. City water will normally be processed, but in an emergency, sea water will be used. Maximum capacity is 125 000 gallons per day. ■

## pumps for boiler systems

The canned motor-pump, developed originally for handling radioactive liquids in pressurized nuclear reactors, is equally at home in conventional boiler circulation systems. Canned pumps for this purpose were developed as early as 1955; now engineers have added some new features that further increase the inherent advantage of these pumps over conventional seal-type units.

The two principal design changes are: a removable stator, which simplifies any problem of maintenance in the event of electrical failure; and the use of carbon steel in the pump, which reduces the cost.

In addition, a series of pumps of different sizes have been designed with many common parts, which leads to simpler maintenance.

Canned motor-pumps have several advantages over conventional pumps. They require no external glands. Valves and instrumentation to provide injection water for sealing conventional pumps are eliminated. No seal maintenance or bearing lubrication is necessary. The canned motor-pump can withstand full temperature and pressure at hot standby conditions. In addition, no adjustments are necessary when the pump is in operation; the pump can be started and stopped at any time at full pressure and temperature. Also, the heat losses from the pump motor are "recovered" since the coolant water is a part of the condensate system.

A prototype of this hermetic gasketed unit has completed over 20 000 hours of operation in a boiler circulation system. Units of the final design have now been in operation for over a year.

The new canned pumps are designed in several sizes with capacities from 4000 to 10 000 gallons per minute with heads up to 40 psi. The units are capable of operating in pressure systems up to 3000 psi. ■

## brushless excitation system for ac generators

A new type of excitation system has been developed, for use in the electric utility industry, in which the collector, collector brushes, commutator, and commutator brushes are eliminated. The system consists of a permanent magnet pilot exciter, an ac main exciter, and a rotating rectifier mounted on the same shaft as the field of the

**Left**—The rotating rectifier of the brushless excitation system.

**Right**—This is the first of two "cross-quad" 3600/3600 turbine generator units being installed in the Bergen Generating Station of the Public Service Electric and Gas Company of New Jersey. This No. 1 Unit was placed in commercial operation in May 1959; Unit No. 2 is scheduled for operation as we go to press.

The turbine is a cross-compound, quadruple-exhaust machine, with both shafts operating at 3600 rpm. The outstanding feature of this design is the use of 3600-rpm turbine and generator for a rating of 290 mw. Each element has small diameter turbine and generator rotors with ratings well within past practice. Turbines are nearly identical, consisting of duplicate low-pressure turbines with double-flow 25-inch low-pressure blades, one connected in tandem to a high pressure and the other to the intermediate turbine

ac turbine generator. The total excitation power requirements, including the power supply of the regulator, are obtained from the generator shaft.

Brushless excitation systems of this type have previously been used in aircraft applications. Recently, this system has been developed for electric utility generators. Both applications use silicon diode rectifiers, which have been tested and found to be ideal. The silicon diode is both small in size and extremely reliable.

The new excitation system functions as follows: the small permanent magnet pilot exciter stator furnishes excitation energy to the regulating system, which in turn energizes the stationary field of the ac main exciter. The ac exciter's rotating armature output is fed along the shaft to the rotating rectifier. The rectifier's output, in turn, is fed along the shaft to the field of the ac turbine generator. Hence, all movable current collecting parts are eliminated, which should result in a very reliable system.

The ac exciter is a proven design with a rotating armature and stationary field. The exciter generates 420-cycle, 3-phase power. The rectifier is made up of silicon diodes, arranged for the dc output desired to meet the requirements of the ac turbine-generator field. Sufficient capacity is provided so that the diodes will not be overloaded even though approximately 30 percent of each phase is out of service. Fuses protect the individual rectifier cells.

The brushless excitation system uses components of such promising reliability that designers hope to eliminate the need for reserve excitation. This should also eliminate the need for the generator field breaker along with the exciter field rheostat and its mechanically operated contacts and space requirements.

First application of the new semiconductor excitation system will be on a 180-kw, 250-volt rotating rectifier system for use on an ac generator of the West Penn Power Company. Studies to date indicate that the brushless excitation system can be designed in any size up through the largest exciter required for ac generators. The brushless exciter will be comparable in size to the space taken by the present dc exciter, gear and collector. If experience verifies the expected reliability, performance, and low maintenance, the new system promises to become the excitation system of the future. ■

## building block regulators

The first new "building-block" design of the 420-cps Mag-A-Stat regulator, announced on these pages last year, went into service in mid-1959. As we go to press, some two dozen regulators for turbo and water-wheel generators will be in service. The functional component design makes the regulator easy to apply to any size machine or application, using standardized components. The next improvement planned by design engineers will be the use of silicon rectifiers throughout, which will provide a space-saving feature. The silicon rectifiers for application in the regulator have been on test for over two years.

*60-Cycle Regulator*—The 420-cps regulator components have been augmented by a new line of 60-cps magnetic amplifiers and regulators. Although the 420-cps magnetic amplifiers permit faster response in the regulating system, the 60-cps system will give sufficient response for many applications. For example, the 420-cps system requires a specially designed exciter, and therefore would be difficult and expensive to apply to an existing machine. On the other hand, the 60-cps system can work with existing exciters, and with a minimum of station modification. Hence, the 60-cps Mag-A-Stat will find application on existing machines, either for replacement of obsolete regulator equipment, or for the addition of regulating equipment. The 60-cps Mag-A-Stat regulator provides all of the maintenance and reliability advantages of the 420-cps system, and further provides an improvement in performance over previous electromechanical regulating systems.

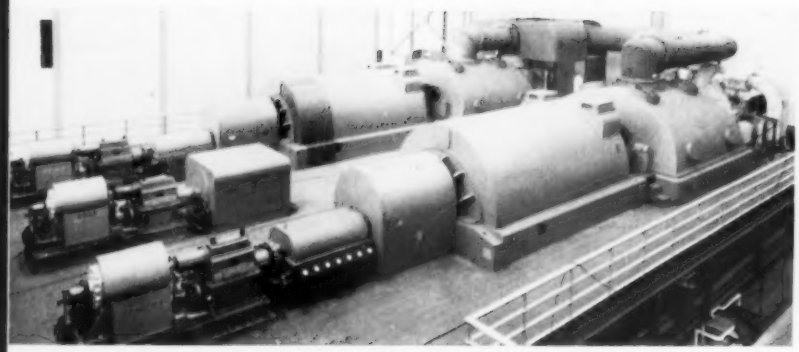
The 60-cps components will provide, in building-block form, regulator and amplifier circuitry for accomplishing almost any function of machine regulation. For example, standard components can regulate voltage, current, power factor, kilowatts or kilovars, and volts per cycle. ■

# TRANSFORMERS

## more advances in vapor cooling

Vapor/gas cooled transformers have followed a steady path of progress since the first unit was installed in 1957. This first unit was a 500-kva network transformer; it was followed by a 7500-kva, 34.5-kv power transformer in 1958.

In 1959, two significant new steps were taken—a gas-insulated tap changer was developed for use on the vapor/gas transformer, and the voltage range was extended from 34.5 to 67 kv. Both of these advances were incorporated in a 7500-kva, 67-kv, three-phase transformer shipped to a southern utility during 1959.



The use of gas insulation in the load tap changer means that no oil is needed anywhere in the transformer tap changer unit, and thus a potential safety hazard is eliminated. While some air-insulated tap changers have been built previously, the use of inert gas under pressure in the tap changer eliminates any explosion hazard, or any possible damage from contaminated or excessively humid air.

The success of the vapor cooling principle in installations to date indicates further extension of the principle to larger units in the future. Immediate goals are to experiment with even higher voltages, and to do further development on units using fluorocarbon vapor alone, i.e., without the sulfur hexafluoride gas. The only purpose of the $SF_6$ in present transformers is to provide insulation during start-up of the transformer, in the period before the transformer is hot enough to vaporize the fluorocarbon. In certain installations, such as generating station transformers, some means of preheating the fluorocarbon liquid may be available, which could eliminate the need for $SF_6$ gas in the unit. ■

## CSP features for larger transformers

The average kva rating of distribution transformers installed on utility lines has increased from 15 kva in 1951 to 25 kva in 1958, and will continue to increase in the future. At the same time the maximum unit size has increased correspondingly. In recognition of this trend, the completely self-protecting (CSP) features of units under 50 kva are being extended to the larger sizes.

To transformer engineers this has meant development of a new circuit breaker for use with the larger ratings. The result is an electrically reclosed (type ER) breaker, which has been first applied to the 167-kva transformer, and will ultimately be adapted to other large sizes.

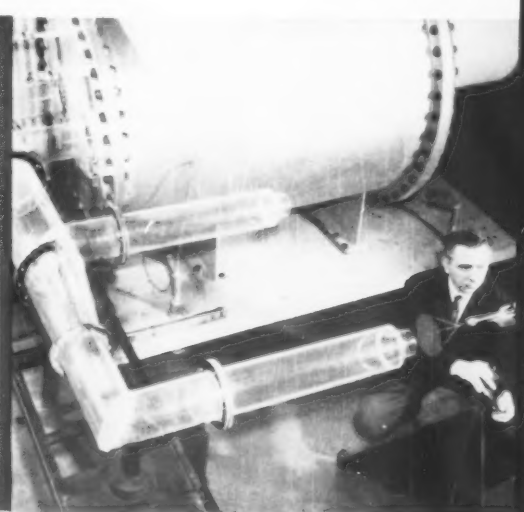
The new ER breaker will interrupt 23 000 amperes at 240 volts per pole. Its contacts will carry 1050 amperes continuously with a temperature rise of less than 15 degrees C. Insulation is above the 30-kv BIL specified for low-voltage windings.

The new breaker has complete electrical control. Both closing and operating mechanisms are activated by magnetic solenoids, which gives greater flexibility of mounting and control of the breaker, and simplifies the mechanical linkage.

For thermal tripping, the high current levels of these large transformers makes the use of a bimetal carrying full transformer load impractical, and for other reasons, a current transformer also would be impractical. Thus a new solution was needed and engineers solved the problem by a pick-up coil—a small pancake coil inductively coupled to the low-voltage leads. This provides a small amount of control energy, enough to supply a small bimetal, which closes a contact to activate the trip coil. For the tripping action itself, a mechanically operated mechanism would have required the usual train of precision linkages needed to gain the necessary mechanical advantage. With the electrically operated tripping, a simple, rugged ele-

**Left** – The Haas Powerhouse, the first underground electric plant built in the United States in 42 years and the only large one, is now in operation on the Pacific Gas and Electric Company's system. These two 75 000-kva vertical water-wheel generators operate at 400 rpm. This unusually high speed is brought about by an operating head of more than 2300 feet. Water to drive the turbines is brought through a 6-mile tunnel and a 4560-foot penstock. The powerhouse is carved out of solid granite, and is 500 feet below the surface and 2000 feet inside the mountain.

**Right** – Shown during model testing is a new crossover pipe design that will simplify the piping arrangement for the new quadflow tandem turbine units. With the new crossover pipe design, only two crossover pipes are used. Each crossover pipe has two inlet connections and two discharge connections so that in effect two crossover pipes are combined into one.



ment—an electromagnet or solenoid—releases the stored spring energy.

The advantages of electrical operation are several. A simple contact-operating mechanism can be used, making the breaker "trip free." Because the breaker is controlled electrically, the control circuit can be modified for automatic reclosing, banked secondary operation, remote control and other schemes. If the contacts must be opened by a lineman using a hookstick on the external handle, the process is simple, since he is turning an electrical switch rather than working an operating linkage. ■

This 333-kva distribution transformer sets a new maximum for pole-top rating.

## still more kva on a pole

Barring the advent of a radically new concept in transformer design, there is probably some upper limit to the amount of kva that can be packed into a pole-top unit. As yet, however, engineers show no signs of being restricted by limits. Two years ago, they upped the maximum pole-top rating to 167 kva. A year ago, they upped it again, to 250 kva. And in 1959 they increased it again, in the form of a new 333-kva unit.

The new distribution transformer was made possible by a redesign of the core and coil assembly. The shell-form core of Hipersil sheet steel is assembled in such a way that magnetically it approaches a continuously wound core. The coils are wound progressively and concentrically. Low-voltage windings are formed of wide copper strips, with one turn per layer; in previous transformers, several copper straps were grouped to make an individual turn.

High-voltage coils are made of rectangular enameled copper straps. High-strength adhesives, applied during the winding operation and later heat cured, make the coil mechanically strong against short-circuit stresses. This process eliminates the need for the usual heavy metal structural braces.

The new 333-kva, 7200-volt unit is about 24 inches in diameter and 48 inches high, from base to bushing tip. This unit weighs but 2100 pounds—which is less than the 167-kva unit of four or five years ago. ■

## overload indicator for transformers

Even if a distribution transformer has ample overload capacity, the use of this capacity may not be economically sound, because the cost of losses jumps rapidly in the overload region. A new indicator for distribution transformers is designed to light up when the economic limit is reached.

An indicator of this type should not be "fooled" by short peaks representing faults or other abnormalities; on the other hand, it should not be so slow that it requires several hours peak before it registers. The new TL indicator is designed to operate between these extremes. While the TL indicator is not an indicating meter, but a signal light, it is designed along the general concepts of a demand meter. It has a time constant of one hour, i.e., it reaches 90 percent of final value in one hour, and full deflection in about two hours.

The indicator can be mounted on the outside of the transformer tank, or at any other convenient location. Two leads from the outer low-voltage bushings must be carried through two openings in the molded case of the indicator. Flow of current in the leads causes a temperature rise at the center of the case proportional to the amount of current flowing. The temperature rise heats a helical bimetal, which in turn rotates an arm in a dial case. When the arm reaches a predetermined angular deflection it closes against a magnet, and this in turn allows current to flow in a small neon tube that serves as a signal light. Once closed, the arm is held by a magnetic pull strong enough that it will not release when temperature drops. The light thus continues to burn until reset manually, which is accomplished by pushing a plastic button on the bottom of the dial case.

The new indicator is calibrated at the factory for a standard trip time, but different values can be selected by an adjusting knob. Thus the indicator can be adapted to various special conditions of operation used by different electric utilities. ■

# SWITCHGEAR

## single-tank breaker ratings increased

The interrupting rating of the outdoor single-tank oil circuit breaker has been extended from 250 to 500 mva at 14.4 kv. At the same time, the interrupting time has been reduced to 3 cycles; even for currents between 25 percent ratings and zero amperes, the interrupting time is essentially 3 cycles.

The interrupters were redesigned using the principles of the tubular-type De-Ion grids that are used on the high-capacity oil circuit breakers. Interruption is accomplished by de-ionizing action, which results from self-generated pressure inside the grid. Shorter arcing time results, particularly on low-current interruptions.

Butt contacts are used to get high-speed contact parting time. These contacts meet the required 40 000-ampere momentary and 25 000-ampere four-second rating. When a 1200-ampere continuous-current rating is required, an additional contact is mounted outside the grid stack.

A new solenoid operating mechanism has also been developed for the breaker. The new mechanism permits a reduction in closing current from 65 to 35 amperes at 125 volts dc, or 230 volts

ac. Hence, a 3-kva transformer has sufficient capacity for breaker closing. ■

## fault initiating switch

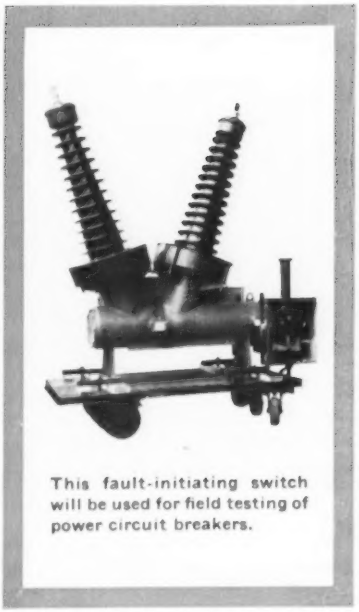
The problem: To initiate a fault on a 230-kv line, with a time consistency of plus or minus 5 electrical degrees on a rising voltage wave, and plus or minus 10 electrical degrees on a falling wave. (Translated into time, this is plus or minus 0.00023 and plus or minus 0.00046 second respectively.) The device was needed by the Bonneville Power Administration for field testing of power circuit breakers on their 230-kv system. This high accuracy is required to control current asymmetry by initiating the fault at a desired point on the 60-cycle wave. In addition to the above requirements, limits were placed on the size and weight of the switch so that it could be transported readily to different test sites.

The answer: A device was needed that was relatively light, had high closing speed with no mechanical variation, and operated in a high dielectric medium to keep arc pre-striking to a minimum. Switchgear engineers fulfilled these requirements by using a spring-closed device, tripped with a high-speed latch. The dielectric medium is sulfur-hexafluoride. As a result, the switch weighs only 5200 pounds, which includes 1500 pounds for special oversize current transformers, needed to measure fault currents accurately. The switch was tested in the Westinghouse High-Power Laboratory to prove its ability to close positively into 58,500 amperes, and its closing time consistency. ■

## magnetic air circuit breakers redesigned

By the end of last year, the complete line of magnetic DH breakers had been redesigned, from 5000 volts, 250,000 mva interrupting capacity to 15,000 volts, 500 mva. However, the new breakers have been kept physically interchangeable with the previous design.

Fundamentally, the arc-interrupting process in a DH breaker consists of drawing an arc in a magnetic field, which is created by the arc current in a series-connected coil; in the magnetic field, the arc tends to rise and lengthen thereby cutting across ceramic arc splitters, which cool the arc until it is extinguished. In the new design, the interruption process has been devised so that the arc is broken into two short arcs for individual interruption of each arc, rather than one long arc. This makes the arc easier to control, and makes possible more efficient use of the magnetic field, arc splitter, and ceramic materials.



This fault-initiating switch will be used for field testing of power circuit breakers.

A second improvement is a diaphragm puffer, used in place of the previous piston design. The puffer provides forced air to push low-current arcs up into the arc chute. By using a diaphragm design, there is no chance of friction developing, which can slow up contact motion. The diaphragm is of molded rubber and has been tested down to minus 65 degrees F.

A third improvement is the application of insulating materials that are both flame retardant and track resistant throughout the breaker design. For example, a synthetic resin coating will improve the surface of phenolic insulators, making them highly track resistant.

A further mechanical improvement is the use of a tilting design arc chute, which can be easily tipped back for inspection and maintenance.

*Stored-Energy Closing Mechanism*— An optional feature of DH breakers is a spring stored-energy closing mechanism, which can reduce closing power requirements. When used in place of a solenoid closing mechanism, a motor and reduction gear compress a spring in 5 to 10 seconds, and latch a retaining linkage. The breaker is then closed by releasing the retaining linkage, either electrically or manually. By drawing closing power over an 8 to 10 second period, rather than ¼ second as required by a solenoid coil, the closing power demand is considerably reduced. In the absence of electrical closing power, the spring can be compressed with a hand crank.

The closing mechanism will have applications where a number of breakers must be closed simultaneously, such as a bank of breakers through which power is fed to a large network system. A second application is in distribution substations, where a Rectox unit with an associated transformer is presently used on each breaker. Here, if bus voltage should be removed, there would be no closing power available. In the stored-energy device, the closing energy would already be stored before power failure, so that breakers could be closed in the absence of bus voltage. ■

## new lightning arrester

A new improved intermediate lightning arrester has been developed for the protection of apparatus in small and medium size substations. The unit is made in voltage ratings from 3 kv through 121 kv.

The new design has several advantages over its predecessor, the Type LVS arrester. To obtain high cantilever strength, a special glaze, used for many years on station-type arresters, is employed. Greater arrester insulation withstand strength is obtained by increased creepage distance over the porcelain housing. The gap elements are the same as those used in the station-type arrester. All units have a relief diaphragm to release excessive pressure in event the unit is damaged and sustained 60-cycle current flows through the arrester. A red side vent plate comes off when the pressure release diaphragm operates, giving visual indication of operation. ■

## capacitor developments

Large metal-enclosed capacitor equipments for distribution substations have been designed for mounting 50-kvar units, replacing the previous 25-kvar capacitor units. Since a 50-kvar capacitor occupies less space than two 25-kvar units and only one fuse is required, the equipments are more compact and have lower overall dimensions. In addition, the equipments are

designed for shipment with capacitors in place. The new unit is supplied in ratings of 1200 to 6000 kvar, in 1200-kvar steps.

*For Capacitor Switching*—A single-pole oil switch (Type CSL) has been designed primarily for switching distribution capacitors, and is rated at 14.4 kv, 200 amperes. The switch has improved switching capability and short-time ratings and performance over its predecessor, the CSO switch. The new switch retains the simple solenoid operating mechanism, but has improved moisture proofing, encapsulated coils of high dielectric strength, improved heavy-duty cut-off switch, and increased magnetic force for opening and closing.

*Capacitor Switching Relay*—A new line of controls for capacitor switching has been designed to prevent unwanted tripping on loss of voltage. One of these devices, a CJ-7 var control, receives a voltage and current signal and responds to the vars of the combination to initiate switching of capacitors. This relay is calibrated to have zero torque when system power factor is unity. A moving contact takes a position depending upon the torque exerted, which is a function of the vars flowing. When the moving contact makes with either the "close" or "trip" adjustable fixed contacts, a fixed time delay is inserted before operating a toggle relay to initiate a switching operation. The new unit replaces the more costly regulating watt or var relay, with the additional advantage of the toggle relay to prevent unwanted tripping upon loss of voltage. The new relay can be adjusted from 250-vars leading to 500-vars lagging. ■

## MEASUREMENT, DISPATCH, PROTECTION

### automatic dispatching

A new automatic dispatching system currently under development for the Cleveland Electric Illuminating Company will contain several unique features. One of the novel features is megawatt-hour bias—a method for controlling unintentional power interchange. A second feature is valve-point loading, which is designed to prevent turbines from operating at valve positions of reduced efficiency.

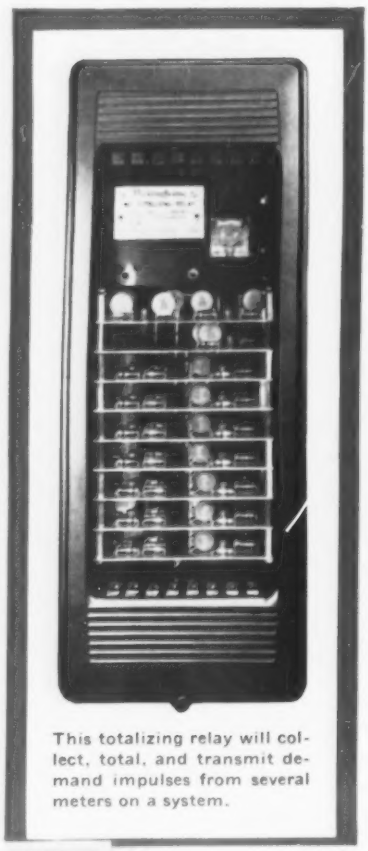
A digital display will show station kilowatt and var outputs, along with system voltages at critical points. A means will also be provided for altering station steam operators to abnormal power requirements.

The system will be composed entirely of static components, such as transistors and magnetic amplifiers, except where the duty is extremely light. For example, slide wires are only used for nonlinear conversions, which take place very slowly. Slide wires will not be operated at a maximum speed in excess of 0.5 degrees per second. ■

### static totalizing relay

A new impulse totalizing relay serves as a "funnel" for collecting, totaling, and transmitting demand impulses from several different meters in a distribution system. And, regardless of the number of input circuits the unit handles, it has but one moving part—the output relay.

Incoming pulses are fed into input channels of the totalizing relay and stored momentarily in a transistorized storage circuit. Storage circuits of the several input channels are electronically scanned and cleared of stored impulses. The stored impulses are passed on in sequence to an output circuit that drives an output relay.



This totalizing relay will collect, total, and transmit demand impulses from several meters on a system.

The new totalizing relay is available with from three to seven input channels and with input/output ratios of 1 to 1, 2 to 1, and 4 to 1. Output rates are 225, 450, and 900 impulses per minute. The cataloged relays employ 225 output impulses per minute, to make them compatible with existing systems without changes in either the input pulsing equipment or the final impulse receiver.

The maximum impulse rate of each input channel is proportional to the input/output ratio and inversely proportional to the number of channels.

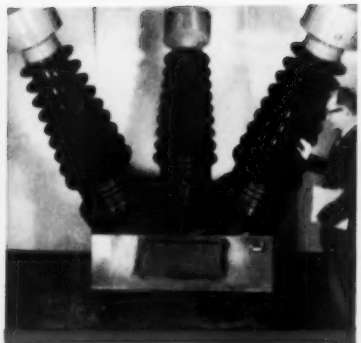
Thanks to the static components, the unit is much more dependable than mechanical totalizing relays, has higher impulse rates, and requires less panel space. ■

### transformers for metering, relaying, and indicating

*Molded Transformers*—The trend toward molded units for potential and current transformers continued this year, with three new units added to the list. Like their predecessors, these transformers are molded of polyester rubber and are thus impervious to industrial contamination and can be used either indoors or out.

Two of these new units are current transformers (Type EMC and ECI), the third is a potential transformer (Type EMPL). The EMC is designed for high-current metering and relaying on low-voltage systems. It can be used with either uninsulated bus bar or cable up to 600 volts, or with insulated primary conductors at higher voltages. The unit is unique in that it can be either base or panel mounted; the primary opening has a diameter of five and a half inches, large enough for either bus bar or cable. The EMC transformer is in the 600-volt class, has a 10-kv BIL, and can handle primary currents from 1200 through 4000 amperes.

The Type ECI is designed primarily for indicating service in switchboard and switchgear applications. Like the EMC, this new unit is also of molded polyester rubber construction and is designed for either base or panel mounting. The ECI is a 600-volt, 10-kv BIL unit and is available in current ratings from 100 through 800



High-voltage three-phase potential transformer. Secondary terminals are grouped.

Hall multiplier watt transducer (*right*) compared with thermal device (*left*).

amperes. The rating factor of this unit has been increased by one-third over the previous unit—from 1.00 to 1.33, which means the transformer has 33 percent more overload capacity.

The new potential transformer, Type EMPL, has been developed for two different voltage classes—600-volt class at 10-kv BIL, or 1200-volt class at 30-kv BIL. The units are designed to maintain 0.3 metering accuracy through 75-volt amperes at 85-percent power factor.

*For High-Voltage Operation*—A new three-phase potential transformer does the work of three conventional single-phase units. The result is a unit that is lighter, and therefore requires less foundation and installation expense. The new transformer (Type APT) has been designed in both 550- and 650-kv BIL ratings. The 550-kv BIL unit is 99 inches tall from base to bushing tips, and measures about 32 by 60 inches at the base; it weighs but 5400 pounds, as compared to 5900 pounds for three conventional single-phase units. Secondary terminals are grouped in one conduit box. ■

## universal meter package for kilowatthour measurement

By a simple switch of bus bars and potential connections, a new universal meter can be converted from one type of metering service to another. In fact, this one meter can be quickly switched to serve any of the basic single and polyphase circuits.

The new meter consists of an S-type polyphase watthour meter, two small current transformers, meter mounting contacts, and a family of interchangeable bus bars, all in a single enclosure. By switching the connections, the unit can be used for these services: single-phase, three-wire, 240 volts; three-phase, three-wire, 240 volts; three-phase, four-wire wye, 120/208 or 277/480 volts; three-phase, four-wire delta, 240 volts; or 120/208-volt network.

Because of its design, the universal meter unit is able to use a single two-stator watthour meter for a variety of applications, thus greatly simplifying stocking and inventory problems. ■

## hall effect transduces watts

The use of the Hall multiplier—a new watt-measuring device—in a new type of wattmeter was announced last year. This year, this same watt-measuring device was put to new use to serve as a watt transducer, where it converts ac watts to a dc millivolt signal. Watt transducers supply a signal, proportional to measured watts, for application to a control device, or to a telemetering transmitter. This field was previously dominated by the thermal converter, a thermocouple device that produced a millivolt signal proportional to watts. However, the new Hall multiplier watt transducer accomplishes the same task at a lower cost, and in less space. A prime advantage, particularly in control circuitry, is the instantaneous speed of response of the watt transducer as compared to a relatively long time constant for the thermal converter.

Two versions of the watt transducer have been designed: the first and simpler produces an unfiltered dc current output in the milliampere range; the second produces a filtered dc millivolt output.

The first version will be used for driving direct-acting external instruments, or control windings of magnetic amplifiers, where there is no sensitivity to ac ripple; the second will be applied where control devices, telemetering transmitters, or potentiometric recorders must have a dc signal relatively free of ripple. ■

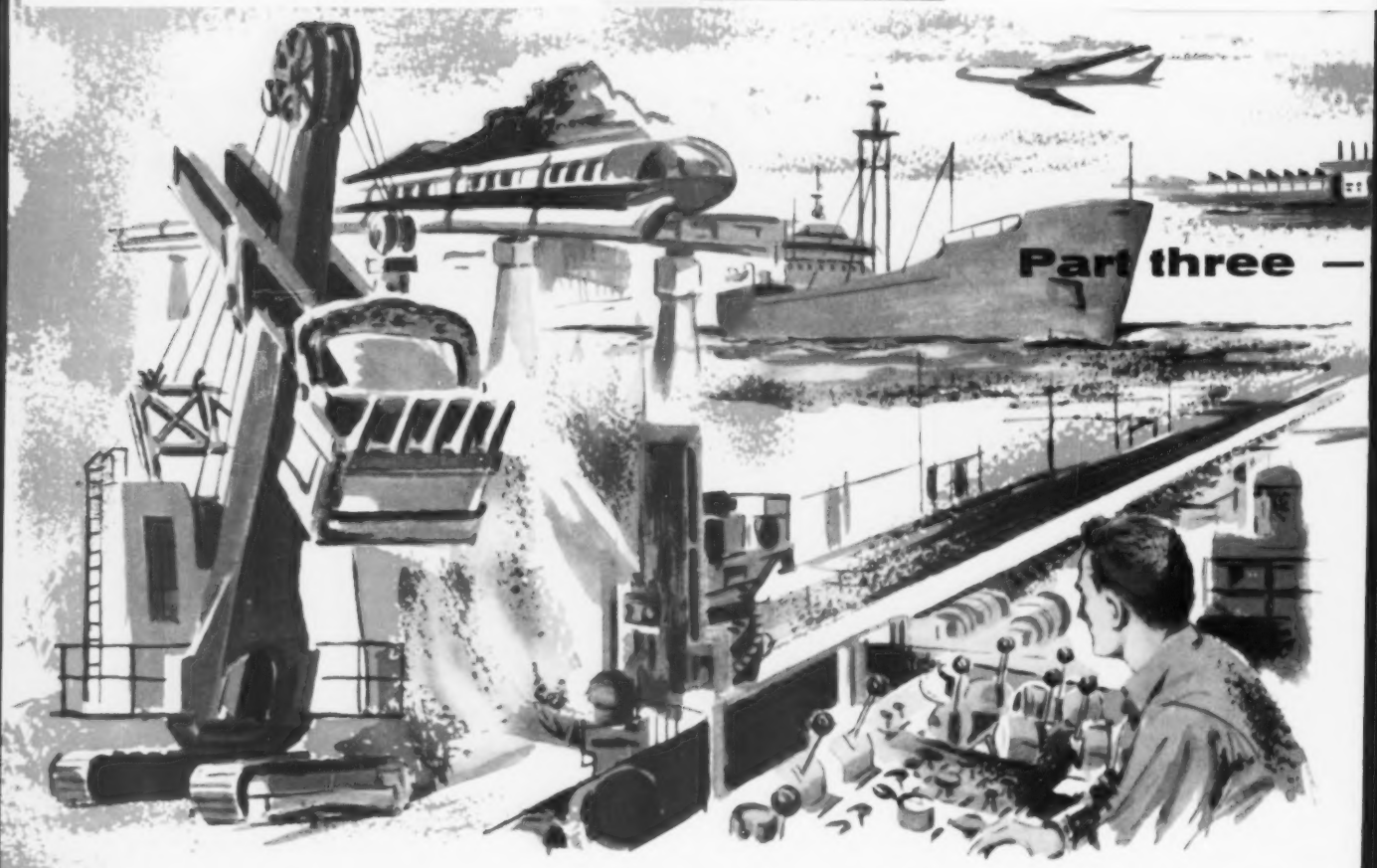
## relay developments

Relay designers made a promising start toward realizing the potential advantages of semiconductors when they developed a new static relay, the type SA, for generator protection. Response of the static relaying circuitry is limited only by the time required for integration (the thinking and command function). The new SA differential generator relay holds promise for low maintenance, better sensitivity, lower operating energy, and more compact construction.

*K-Dar Microwave Relaying*—The K-Dar compensator relays for directional-distance relaying on transmission circuits were described on these pages two years ago. These relays have been used in a new K-Dar directional comparison-trip system that has been designed for protective relaying with microwave channels.

Previous protective-relay systems have used one of two principles: the directional comparison-blocking system, or the transfer-trip system. With the blocking system, if the fault is external to the protected line section, a blocking signal is transmitted which prevents remote terminals from tripping. With the transfer-trip system, the terminal that detects an internal fault initiates a trip signal to the remote terminal to isolate a faulted line section.

In the development of the new K-Dar microwave trip scheme, an attempt was made to incorporate the best features of both the blocking and transfer-trip systems. In the K-Dar system, a trip request is transmitted by a terminal in the direction in which it "sees" a fault. Hence, the terminals at each end of a line will send trip requests to each other, thereby answering the other's trip request, so that breaker trip circuits are energized at each terminal to clear the fault. High-speed simultaneous clearing of all types of line faults can be effected with the K-Dar directional comparison-trip system. Faster and more complete protection is provided than is available with either the blocking or transfer-trip systems. ■




## DRIVES AND CONTROL

### speedometers and rulers

A vital link between an industrial process line and a control system is the sensing device, which tells the control what the line is doing. The bulk of process-line information fed to industrial controls consists of line speed, line footage, position of screwdowns, and draw between sections—all of which can be boiled down to the questions of how fast and how far.

Because the trend today is to high-speed digital control systems, and because digital indicators are relatively free from drift, digital speed and position indicators are in demand. But they must possess high accuracy, be dependable, and, importantly, withstand the punishment of industrial use, for the floor of a steel mill is no place for a fragile sensing instrument.

Two digital indicators have now been designed for indication of speed and position. They are called Pulstac and Rotrac, respectively.

The Pulstac indicator consists of a barium ferrite wheel, which is radially magnetized, and a horseshoe-shaped steel pickup unit. Because the distance between poles on the pickup unit is equal to the distance between unlike poles on the wheel, the direction of magnetization in the pickup changes as the wheel rotates; no contact is made between the wheel and the pickup unit. Changes in magnetization are translated into alternating current through a wire wound on the pickup unit. The electrical output is fed into a transistor amplifier, where the wave is amplified and clipped to produce a square wave. Thus the frequency of the square wave is proportional to the rotational speed of the wheel, and, in turn, the speed of a conveyor, or motor.

The wheel can be magnetized with anywhere from 1 to 1000 magnetic poles. Thus, high resolution can be obtained at slow speeds. The unit can operate over a speed range from 20 to 10 000 rpm.

The entire assembly is enclosed within a cast-aluminum frame, which is watertight and dustproof. The output of the speed-sensing device is 24 volts with only 100 ohms impedance, so that the signal can be transmitted over an appreciable distance without difficulty. The device, designed specifically for industrial use, can operate in ambient temperatures from minus 20 to plus 100 degrees C.

Indicating position is a slightly different matter, for position must be indicated at zero speed, as well as when there is movement. This has been accomplished with a device that yields pulses as a function of rotation, with one difference; it does not depend upon speed to give an indication of position. This device, Rotrac, consists of two discs; on each is impregnated a radial bifilar winding. One disc is the rotor, and is attached to the shaft. The other disc is the stator, and is stationary. An alternating current of 100 kc, sent through the radial windings of the rotor, produces a fringe field that excites a current in the bifilar winding of the stator. When the stator and rotor windings are matched, a maximum voltage is produced in the stator. When the windings are equidistant, the induced voltage in the stator is cancelled. As the rotor turns, a sine wave is produced, which after amplification runs through a detector, is shaped, and emerges as a square wave.

The feature of the device is that there is no contact made to produce the digital pulses. In addition, slip

rings to provide power to the rotor are also eliminated. Instead power is provided by induction through slip-ring transformers. ■

## new speed regulator cubicle

Several features have been incorporated in a redesign of a speed regulator cubicle. Among the most important are a reduction in size, and at the same time, an increase in accessibility for testing and maintenance.

Previously, all equipment including regulation equipment, contactors, and rectifiers were mounted on panels. About three panels were required for each stand. In addition, to provide accessibility, a cabinet depth of about 72 inches was required.

Now, all equipment is located in one cabinet, only 44 inches deep. Several developments have made this reduction possible. First of all, silicon diodes have replaced selenium diodes, with an attendant reduction in size. And secondly, a new Magamp regulator is used, which also is reduced in size.

Careful arrangement of equipment also reduces the size of the cabinet. For instance, all regulating equipment is mounted on the back door. When the back door is opened, all connectors between the regulating equipment and relays are easily accessible. Also, the rear wiring of the relays is easily reached from the inside panel.

Meters and recording equipment are mounted on the front door. With the door open, relays, disconnect switches, and motor-operated rheostats are readily accessible. In addition, by using higher gain Magamp units, smaller motor-operated rheostats can be used. Previously, the motor-operated rheostat was about five feet high, and had to be mounted on the floor. Now, they too can be included in the cabinet.

Troubleshooting has also been greatly simplified. All leads needed for testing circuits are brought out to a 22-point plug in the front of the cabinet. A test console can be used, with a patchboard for all troubleshooting.

In addition, each cubicle can be de-energized while the mill is running, provided the stand for the cubicle is dummied. ■

## numerical control for lathes

In addition to directing a sequence of operations in a mammoth steel mill, Prodac control will now oversee the movements of a smaller, but nonetheless just as complicated a machine—a turret lathe.

For instance, on its first application to a Gisholt automatic turret lathe, this numerical control will automatically, from information supplied by punched tape: operate a face check for six turret faces; control the turret carriage traverse; select six rates for the turret carriage feed rate; control the turret carriage direction; select four different spindle speeds; automatically operate an instantaneous turret carriage reversal; control the

Rod exits from this mill at speeds up to 6500 feet per minute, giving the Sheffield Division of the Armco Steel Corporation title to the world's fastest rod mill. The speed of each of the 23 stands is controlled from the operator's pulpit. After the operator makes the settings, automatic regulation holds speed variations to ¼ percent.

The mill receives billets from the reheating furnace (upper left). Billets travel through the roughing mill, intermediate mill, looping mill, and into a six-stand rod finishing train. From there, they pass through a four-stage high-pressure water descaler and are coiled on laying reels.

High speed may not be the only record set here. A billet made a complete journey through the mill the second day the furnace was fired. The day after, rods were being rolled and coiled through all three stands.

Ease of decoding the counter for display is a feature of this new counting circuitry.

turret carriage position; and program dwells and cycle stops.

As if this were not enough, the control will also select two spindle-motor speeds; control the spindle direction; control the carriage drive pressure; direct the tool relief operation; control the threading attachment operation; direct the turret facing attachment operation; control the automatic collect operation; and control the recipromatic operation. All this information can be fed into the Prodac control via an eight-channel, one-inch wide punched tape.

The control embodies the usual Prodac circuitry consisting of NOR elements, and a new packaging scheme, wherein the NOR elements are located on functional blocks for easy maintenance.

The obvious advantage of such a numerical program control is that when the machine is faced with a number of repetitive operations, the operator can use his time more effectively, as the machine is under complete automatic control. In addition, with high-speed digital control, the lathe can be stopped, started, drills changed, and other operations performed more rapidly than with manual operation. ■

## digital speedometer

A transistorized pulse-counting device, combined with a novel counting circuit, has produced a digital counter that can be used to give a total footage count on a roll; or when combined with a crystal-controlled timing circuit, the pulse counter will provide extremely accurate absolute speed indication or absolute speed difference indication.

The device becomes a "draw indicator" when used for determining speed difference between two sections of a paper machine. To determine draw, a reading is taken from one section; then the counter is switched to the other section to obtain a second count. The difference becomes an extremely accurate indication of speed difference, or draw, between sections.

The indicator is ideally suited to paper machines, where for a given grade of paper, the draw between sections is originally set up empirically. With this extremely accurate draw indication now possible, paper machine operators can set the draw to a previously determined setting for a given grade of paper.

The pulses for the counter are obtained from reluctance pickups, which count notches or teeth on wheels connected to the section in drive shafts.

The counting circuitry employs a combination of five decade counters cascaded to obtain a five-place reading. A major advantage of this type of counter over other digital counters, such as a binary counter, is the ease of decoding the counter for a numerical display. The counter has provisions for both read-out and print-out. ■

## CONTROL AND DISTRIBUTION DEVICES

Because low-voltage distribution and control equipment is applied in a multitude of industries and must meet many different requirements, it is only natural that a new crop of these devices appear each year to cope with new applications and to improve performance of old equipment. Here are a few from last year:

*Flush Pushbuttons* prevent accidental operation of machines, but this is only one advantage of this new design. Seven different color caps can be easily snapped on the button by removing the clamp ring. In addition, the connection blocks are shallow and can be stacked to provide for multiple control circuits. The angled terminals

This two-car incline at Lookout Mountain in Tennessee has been outfitted with a modern ac drive one that accelerates and decelerates smoothly because the two 100-hp wound-rotor drive motors at the top of the mountain are controlled with a reversing two-phase saturable reactor control.

The operator at the powerhouse can select five constant-speed points, which are independent of load (from 60 to 600 feet per minute), to accelerate and decelerate the cars on their way up and down the 5200-foot slope. The advantage of this type of control is that all reversing and speed control is accomplished with four primary reactors, eliminating jack-rabbit starts and maintenance normally associated with contactor-type ac drives. For instance, a contactor-type drive builds up torque in 1/120 of a second whereas this drive builds up torque in 2/5 of a second, or 50 times slower.

are easily accessible even when the blocks are stacked.

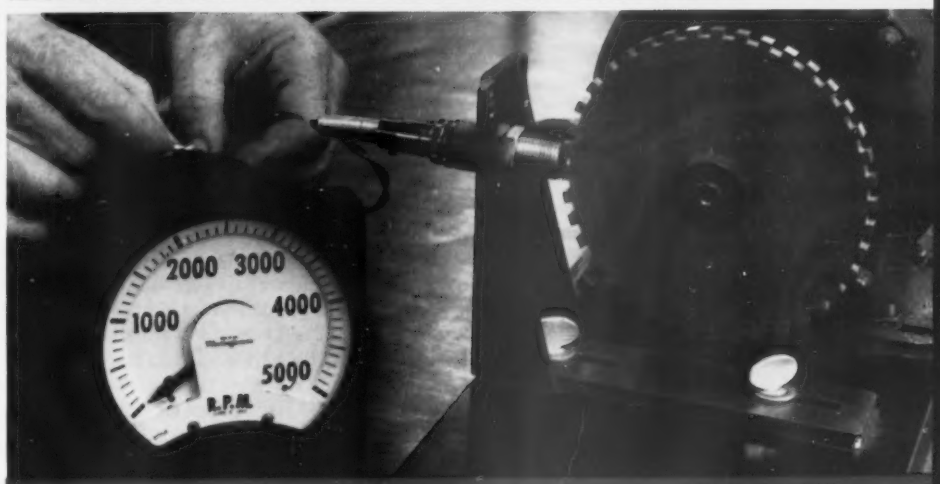
*High-Frequency Bus Duct* has been developed for operation in the range of 180 to 20 000 cycles per second. Because of careful designing, the voltage drop is only one volt per hundred feet at 400 cycles. Equally important is the ease with which the bus can be installed and rearranged. The duct work has been outfitted with conventional type fittings, such as flange sections, tees, crossovers, and end closers. Power can be obtained at 30-foot intervals with plug-in units.

*Molded-Case Circuit Breakers* have climbed to higher interrupting ratings, while maintaining the same physical size as lower rated breakers. Through the use of a new molding compound and other design improvements, a circuit breaker (Mark 75) has been developed that can interrupt 75 000 amperes at 240 volts, a-c. The breaker is made in four frame sizes: HF, HK, HKL, and HLM.

*Combination Safety Starters* were designed to the specifications of automobile manufacturers, and consequently these starters incorporate a unique system of interlocks for maximum safety to operating personnel. For instance, the on-off handle is permanently attached to the disconnect, even when the door is opened, so that the operating condition of the starter is indicated at all times. Special attention has been given to interlocking the disconnect switch with the door. An interlock prevents opening the door when the switch is in the "on" position. After the door has been opened, another interlock prevents accidental operation of the disconnect; when required, the disconnect interlock can be deliberately voided to operate the on-off handle for instance, when an electrician is working on the breaker. The door must be tightly shut before the starter can again be energized. Both the disconnect switch and the door can be padlocked to prevent unauthorized operation of the breaker, and unauthorized entry into the cabinet. But even without padlocks, the door cannot be opened without a screwdriver, further discouraging unauthorized entry. ■

## low-voltage switchgear

*Manual Spring Closing Mechanism*— A new low voltage circuit breaker




**Top**—Because this wheel excavator, designed by the United Electric Coal Companies, can dig and transport overburden on a continuous basis, it can move twice as much earth as a conventional shovel—up to 5250 tons an hour.

In operation, the excavator wheel is set turning, and the cab and boom are pivoted on the turntable, making a swath in the hillside. For the next pass, the boom is extended and the swing reversed.

Contributing to the high productive capacity of this machine are Magamp exciter controls for the dc wheel motor and two dc swing motors. Through the control, the speed of the swing motors is locked to the load of the wheel motor so that a constant amount of earth is deposited on the main conveyor. Previously, the operator had to control the speed of the wheel and swing to prevent the conveyor from overloading and spilling. With the Magamp exciter control, the operator merely sets the main switch for full power. The speed of the swing automatically changes to maintain a constant volume of overburden.

**Bottom**—This new speed-indicating device was developed for use with small turbines. Its principal advantage is that no mechanical connection is required between the indicating device and the rotating shaft. The speed of the rotating part is sensed by an electromagnetic pickup, located near a gear or notched shaft. This signal is applied to an all-static circuit, which transforms the pulses from the pickup to a dc millivolt signal. The output signal magnitude is proportional to pulse frequency. Since most of the power for operating the unit is obtained from an external voltage source, the input or pickup power required to operate the trigger action is extremely small. By proper design of the gear or notched shaft, the device can be adapted to almost any rpm range desired.

closing mechanism has been developed. In this new manual mechanism, the speed and force with which the breaker contacts close is determined by the designer and is independent of the strength and skill of the operator. This permits the safe use of manually operated breakers with delayed tripping on circuits with possible fault currents up to 50 000 amperes. Previously, manually closed breakers could not be used with delayed tripping on circuits with fault currents above 15 000 amperes. The new closing mechanism has a simple over-center toggle linkage system, which releases a compressed spring to close the breaker contacts rapidly and completely near the end of the operating handle motion. This manual spring closing mechanism can now be supplied on low-voltage air breakers with rated interrupting capacities of 15 000, 25 000 and 50 000 amperes.

*Improved Bus Insulation*—New molded bus supports and spool type bus braces have been developed using glass polyester materials. This brings to low-voltage metal-enclosed switchgear the advantages of flame retardance and track resistance. The glass polyester materials are much superior to the cellulose phenolic materials previously used.

*Service Entrance Protector*—At the place where supply lines enter large buildings, it is necessary to provide fault protection and means to disconnect manually the entire supply to the building in case of emergency such as fire. For this use a new line of service entrance protectors has been developed rated 600 volts and up to 4000 amperes continuously. High interrupting capacity current-limiting fuses provide the short-circuit protection. Spring-opened, snap-action, breaker type contacts and interrupters give positive clearing of any currents which may exist when an emergency manual opening is made. ■

## MOTORS

### computers for constant torque

Conventionally, torque of a wound-rotor motor is maintained by changing the resistance values of the secondary circuit with contactors; about eight different values are required. However, instead of producing constant torque, the torque fluctuates about the desired value as the motor speed increases.

Constant torque can be maintained with another type of secondary circuit, using a combination of reactors and resistors, but up to now the values of reactance and resistance were not easily calculated.

The equivalent circuit for this secondary circuit consists of a series and parallel arrangement of reactors and resistors, all of which can be considered as variables in the calculation. The determination of these values, then, reduces to a vast number of trial and error calculations—a method which is easily handled by a digital computer.

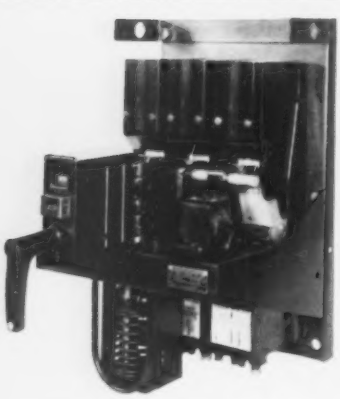
By using a digital computer, calculation time has been reduced from about 5 weeks to a mere 20 minutes. This shorter calculation time permits this better method of torque control to be used in more applications. ■

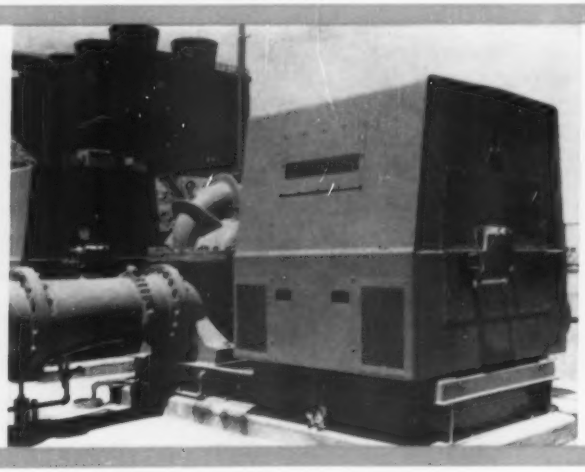
### digital designs for motors

All large induction motors of 200 hp and above are given the equivalent of two man-years' calculation—compressed into ten minutes of high-speed digital computer time. The computer calculates and evaluates all practical designs for a given set of specifications, chooses those that are most efficient, selects the most economical materials and parts, calculates performance data, and prints out the information. This high-speed process eliminates the large backlog of designs that used to pile up in the engineering department during periods of peak sales.

For example, developing detailed and accurate formulas for induction motor designs required the correlation of some 26 design variables. Logical and consistent routines and subroutines for the formulas were developed and translated into machine language. The complete job required some 11 man-years of engineering development time, and $1\frac{1}{2}$ man-years of work by cost analysis engineers.

The use of computers for handling production work in design sections is changing the nature of the design engineer's function. With such a computer program engineering departments can concentrate on developing improved design formulas and computation methods. ■





**Left**—The spring-closing mechanism of the low-voltage breaker permits safe manual closing up to 50 000 amperes.

**Right**—This 800-hp weather-protected F A motor is installed in a fluid catalytic cracking plant. The F A motor, in which the wound stator is a component independent of the motor housing, has been built in all sizes and types, ranging from 150 hp, 450 rpm to 4000 hp, 3600 rpm.

## FOR INDUSTRIAL PROCESSES

### gas turbines for blast furnace blowing

The industrial gas turbine has joined forces with the blast furnace; blast furnace gas, produced by furnace operation, can be used to drive a gas turbine, which in turn pumps fresh air back into the furnace. In the past, blast-furnace gas has been burned in a steam boiler; a steam turbine powered the blast furnace air blower. With a gas turbine installation, the boiler has been completely eliminated along with water requirements; operating costs are reduced and cycle efficiency improved. Furthermore, space requirements are less, which often permits gas turbine installation in existing structures. The first blast-furnace blowing gas turbine in this country is being installed in the U.S. Steel Corporation's South Works in Chicago. This unit will have a capacity of 125 000 cfm, at 35 psig.

The gas-turbine blower consists of two axial-flow compressors, driven by a turbine. One compressor pressurizes blast-furnace fuel gas and the other pressurizes air for feeding to the gas-turbine combustor and to the blast furnace. Low heat content blast-furnace gas and air are fed to a single combustor, a unique feature of this turbine.

The unit is started on distillate oil, and once heated is switched to blast-furnace gas.

This new application again illustrates the versatility of the gas turbine for integration into process lines.

### static frequency tripler for ozone generators

Ozone generators are frequently used in chemical, industrial, and water treatment plants; for example, in water treatment, ozonated air is bubbled up through the water to remove oxidizable materials that often affect the taste of the water.

The ozone generators have unusual loading characteristics, and these in turn require an unusual power supply. For a constant supply voltage, the output of the ozonator increases as the frequency is raised; this brought about a need for an economical and high-efficiency source of high-frequency power. While this power can be produced by rotating frequency multipliers, for this application this method was uneconomical. Engineers have now found a solution in the form of a static frequency tripler.

The new frequency tripler is essentially three single-phase transformers connected in a wye-delta bank, with one corner of the secondary delta open. The primary wye winding is supplied from a three-phase, three-wire source. The supply voltage is increased above the normal voltage rating of the primary winding so that the core is operated well above the knee of its saturation curve.

Under this condition, a substantial third harmonic voltage appears across the open corner of the secondary delta winding, and when a load is connected to this open corner, triple frequency currents flow. Output voltage of any desired value can be achieved by choosing the proper turns ratio of the single-phase transformers.

This principle of frequency tripling is not new, but for the ozonator load, solutions to many problems had to be found. For one thing, the tripler has a large change of output voltage for a small change in supply voltage. Thus the ozonator would be subjected to large changes in input power for small changes in input voltage. To eliminate this problem, engineers used a saturable-core reactor connected in the output of the tripler. A magnetic amplifier voltage regulator senses the voltage input and output of the tripler and adjusts the direct current in the reactor to maintain constant output voltage.

The saturable reactor is also made to serve another purpose. For proper operation, the frequency tripler requires a load whose power factor lies in a narrow range; the reactor maintains the load power factor within the required limits.

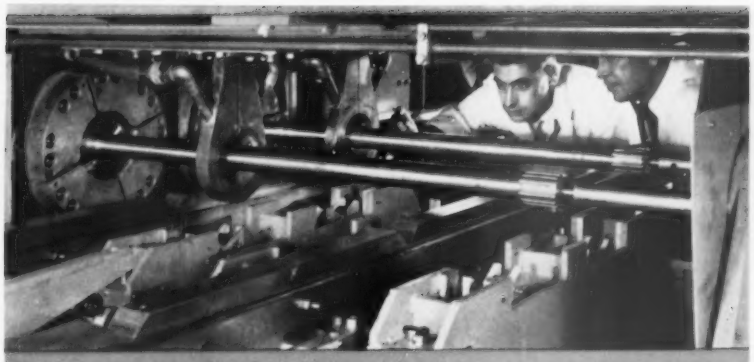
The static frequency tripler inherently has a low lagging power factor on the input side, necessitating some form of correction to make the device acceptable as an industrial equipment. Regular capacitors across the input would not work because of the high harmonic content of the line currents.

Therefore, a special filter circuit was devised, with the power factor correcting capacitors as part of the circuit. The filter circuit allowed these capacitors to be used for power factor correction.

These and a number of other problems were solved in a unit that is rated at 480 volts, three phase, 60 cycles on the input side, with a single-phase, 180-cycle, 70-kw output to an ozonator load.

A total of 15 single-phase core and coils units, including three single-phase transformers and various reactors, are assembled in the one tank of this static frequency tripler.

The static frequency tripler was built for the Welsbach Corporation for use with their ozone generators. ■



This low-distortion axle hardening machine is the latest in a series of developments in axle hardening techniques by induction heating over the last few years. In the past, the hardening process has produced distortion, which required subsequent manual straightening. This new induction heating equipment maintains the original straightness tolerances of the axle, and eliminates the straightening operation completely. The machine can achieve maximum hardness—for example, with 1041 carbon steel, test samples show a Brinell hardness number of 550; tensile strength is 290 000 psi, as compared to 185 000 psi obtained by other hardening methods.

## SEMICONDUCTORS AND ELECTRONICS

### power control with semiconductors

Control of large amounts of power with semiconductor devices is now becoming a reality. For instance the transistor, used in scattered low-power, low-temperature applications five years ago, can now handle 20 amperes with a gain of 10, with a maximum current capability of 30 amperes at an ambient temperature of 150 degrees C. When operated as a switch, the silicon transistor can effectively handle 5 kw of power. This unit is essentially a scaled-up version of a 5-ampere transistor; the use of better materials and more refined techniques resulted in a saturation resistance—the key factor in current rating—of less than 1/10 of an ohm at rated current. Engineers are now concentrating on a further reduction in saturation resistance—to increase current rating to 50 amperes.

The Trinistor, a three-terminal multi-junction silicon NPNP switch, is already giving the transistor stiff competition in high-power switching applications. Not only does the Trinistor have an efficiency of 99 percent, but it can switch in less than 0.02 microseconds.

If no input signal is supplied to the base terminal, the device blocks full rated voltage in the forward or conducting direction. When a base signal of two to five volts is applied, the device switches from a blocking to a conducting condition, characterized by a low forward drop similar to that of a conventional silicon diode. In the reverse direction, like a conventional silicon diode, the device blocks up to rated voltage.

To date a 10 and a 30–45 kw unit have been built, which can be convection cooled when mounted to an appropriate heat sink. Another experimental unit has been built that can switch 100 amperes at 400 volts, again with convection cooling. Ultimately, engineers expect to reach the 100 kw level. ■

### digital computers

Designers of military electronic digital computing systems are working on a comprehensive circuit standardization program. Digital computers normally consist of maze of flip-flop circuits, gating circuits, multi-vibrators, and many others. Analog computers require such circuits as oscillators and amplifiers. Design engineers have designed and built a total of 87 semiconductor circuit boards, which are applicable to both analog and digital circuitry. This stable of cards, which can be easily assembled in a "plug-in" rack, will provide all the functions needed in almost any application of analog and/or digital circuitry.

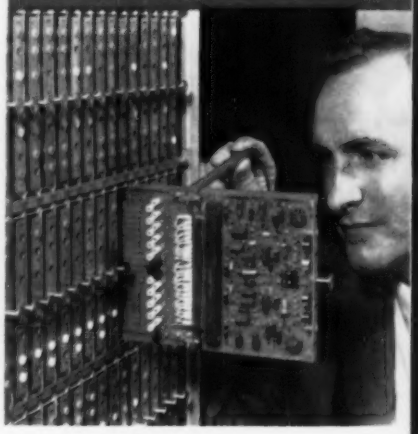
The circuit boards employ both germanium and silicon transistors, depending upon application requirements. They are designed for satisfactory operation over extremes of temperature, supply voltage variation, and component tolerance. For example, the transistorized modules will operate satisfactorily from minus 25 to plus 65 degrees C.

*Analog-to-Digital Converter*—One of the first applications of the newly designed semiconductor modules is in an analog-to-digital converter, which was developed for the Air Force for use on the advanced Bomarc ground-control system. The unit is applicable to any system where analog sensors are employed, but with a digital-type computer. The converter can translate information at a high rate, up to 25 000 voltage readings per second. The unit is accurate to within 1/10 percent and covers an input voltage range of plus or minus 35 volts. By using silicon semiconductors in the plug-in modules, the device will operate over a temperature range of minus 55 to plus 100 degrees C. The unit is distinctive in that it has an extremely high input impedance, so that it can accept almost any analog sensor with no need for an input amplifier. The output is a 10-bit parallel binary number.

*Automatic Wiring*—Designers of digital computer systems have worked out a new method of presenting wiring information, using a logic diagram rather than a circuit diagram. The new system is made necessary by digital equipment that is extremely complex; for example, a typical piece of equipment has 3000 wires and 6000 connections in a single drawer, so that a circuit diagram, as such, would be extremely complex and difficult to follow. Therefore, engineers have devised a method of using a logic diagram and building up a "running list," which lists each wire and an "address" for each end.

**Top**—A new principle is employed to make this mobile x-ray unit explosion safe for operating-room use. Air is taken from above the five-foot level, where gases are considered nonexplosive, and pumped into the unit under pressure, thereby preventing the explosive anesthetic gases, which are heavier than air, from entering the unit. Previously, this was accomplished with bottled gas in sealed pressurized units. However, the air-flow pressurizing system eliminates the inconveniences, expense, and maintenance of gas bottles, and permits on-the-spot servicing. The air-flow system also cools the electrical components in the semi-closed system, and permits increased ratings over the previous pressurized gas system.

**Bottom**—Standardized semiconductor modules are used in this analog-to-digital converter.



This list is compiled initially by an engineer, who writes down all wires, and addresses of each end, which are coded on a "street address" system—by level, connector, pin number, etc. This list is then put on punched cards, and a computer programmed with information of address locations, rules for lengths of wiring, wiring paths, etc., automatically prints out a list of all wires, by length, complete with an address for each end. Furthermore, the computer compilation serves as a double check on the engineer's original information.

By using this technique, a saving in engineering time results, drafting is completely eliminated from the manufacturing information, and wiring time is cut in half. ■

## radar developments

Radar range is proportional to the fourth root of the average radiated power, so that a huge increase in peak pulse power is required to produce a significant increase in range. In conventional radar systems, the transmitted radar signal consists of high peak pulses of r-f energy separated by an empty period, which is determined by the maximum detection distance. Hence, average power could be increased only by very large increases in pulse power. And the extremely high-voltage and high-power peaks required for a substantial increase in average power create many problems.

However, radar designers have a new answer to the problem—a novel long-pulse radar system, which in effect keeps peak power low, but by "stretching" the pulse, maintains high average power. The heart of this new radar system is an "all-pass" filter, which has nonlinear frequency characteristics, so that all frequencies will pass through the filter, but with different phase shift for each frequency. Hence, a pulse, which theoretically consists of many frequencies, is in effect distorted, or "stretched" a planned number of times by this time-delay action. At the receiver, the reflected pulse is passed through the same type of all-pass filter, which recompresses the pulse to its original length. Hence, the long pulse radar can give the equivalent resolution of a short pulse.

The all-pass filter consists of several individual sections, passing all frequency components, but shifting each frequency component a different amount in time. In filter design terminology, the filter consists of a second-order lattice, which eliminates half of the coils to achieve the same effect, thereby economizing on space, weight, and volume. The need for this is illustrated by the fact that in a single set of equipment almost 1000 high-quality coils are required. The filter is embedded in a plastic-film material, which provides rigidity, yet does not change electrical characteristics of the embedded circuit.

*Paraballoons in Space*—Radar engineers are devising some new applications for the Paraballoon antenna—the light-weight, inflated antenna design developed for the U.S. Air Force. In its original design, the antenna consisted of two paraboloids—one coated on the inside with vaporized aluminum to form a radar reflector—joined at the rims and inflated. Westinghouse designers envision several possible applications for this same geometric configuration in space. Under consideration are: a collector of solar energy to power auxiliary equipment; an infrared reflector, which could be used for strategic reconnaissance and mapping; a radar antenna for long-range target acquisition and observation; and an antenna for a world-wide communications network.

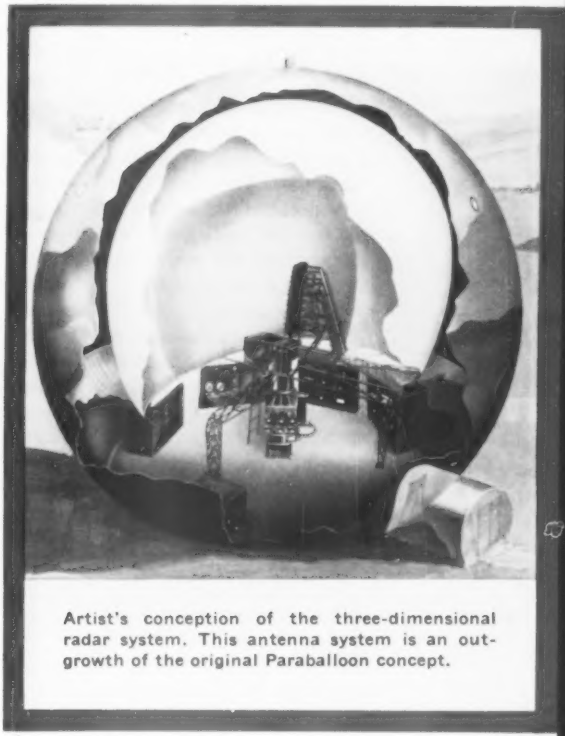
Designers are presently thinking along the following lines: the device would be constructed of light-weight, collapsible fabric or plastic film, so that the total weight of a 30-foot paraboloid collector would not exceed 100 pounds, and would collapse into about 2 cubic feet. Once in space, the paraboloid would be inflated with bottled gas. Pressure would be maintained for a short period to allow for rigidization through temperature stabilization and a plasticizer release. In weightless space, once the unit has stabilized, the front cover could be chemically "burned" loose and ejected thereby providing a permanently unobstructed path of radiation from the sun to the collector. A solar power supply requires a large aperture for maximum energy pickup and should be constantly oriented to the sun. With a suitable method for absorbing solar energy and converting it to electrical power, 10 to 15 hp should be available from such a solar power supply.

The unit seems an ideal device for space application since an antenna used in outer space must initially be packaged in a small volume for launching, and then be reliably and automatically erected in space. The air-inflated antenna can meet these requirements with ease at the present state of the art.

*Three-Dimensional Radar*—A new radar system has been developed that, in addition to deriving azimuth and range information, can determine target height. This additional function is accomplished with a multiple-beam antenna pattern, as opposed to the conventional single-beam antenna pattern. By determining which beam contains the target, the elevation angle is obtained, which is fed to a computer to obtain target height. The system employs a single antenna, with stacked beams. This new radar can replace a complex consisting of a search radar plus a multiplicity of height-finding radars, with advantages in simplicity, weight, and mobility. ■

## magnetic fluxmeter

Without exception, the best approach to a problem is a reduction to funda-



Artist's conception of the three-dimensional radar system. This antenna system is an outgrowth of the original Paraballoon concept.

mentals—this is exactly what materials engineers have done in developing a fluxmeter for magnetic field measurements.

In addition to accuracy and sensitivity, a fluxmeter for this application should possess a small sample volume—the sample volume being the volume within a magnetic field used to interrogate the field strength.

To meet these requirements, engineers turned to the most fundamental method for detecting a magnetic field—a single-turn conductor. They placed the single turn of wire on a flat probe, which is coupled to an ultrasonic transducer. As the probe and wire oscillate in the field, an alternating current is produced. The height of the current wave form as seen on an oscilloscope is a measure of the field strength. The oscilloscope can then be calibrated by inserting the probe into a measured field.

By using a single turn of wire 1/16 inch in length, and oscillating it at 48 kilocycles per second for a distance of plus or minus 0.0002 inch, the sampling area has been reduced to a mere $2.5 \times 10^{-5}$ square inch. Looking at it in another way, a magnetic field can be resolved into increments as small as 0.0004 inch. The probe is only 0.025 inch thick, allowing measurements in air gaps as small as 0.03 inch. ■

## better eyes for infrared

Two characteristics of infrared radiation are of particular interest to designers of aircraft guidance, reconnaissance, fire control, and warning systems. First, the shorter wavelength of infrared radiation gives it much better resolution powers than its lower frequency neighbor, radar. An object that is merely a pip on a radar scope can have recognizable detail with infrared detection equipment. Second, and even more important, is the fact that all things above absolute zero are radiators of infrared energy. Hence, the infrared system is a passive system, undetectable by the enemy.

The key element of an infrared system is the detector. Last year on these pages, we announced a major step forward in mechanical scan systems—the development of a very sensitive detector that can sense wavelengths up to 10 microns, and with a response 10 times faster than any previously measured photoconductive detector. With this device, Air Arm engineers are presently designing a high-speed, low-altitude reconnaissance system. This same infrared sensor material—a gold-doped germanium crystal that changes in electrical conductivity when infrared radiation is absorbed—is being used by research scientists to develop an infrared pyrometer. By making measurements simultaneously in two color regions (at two different wave-lengths), the temperature of the viewed object can be instantaneously and accurately determined. This is because of the fact that the distribution of energy with wave-length shifts in a known manner as the temperature changes. Temperature differentiation will give designers of infrared systems one further dimension with which to work. The new "two-color" infrared detector is being developed under a contract with the Air Force's Wright Air Development Center.

A second form of infrared system receiving much attention is the imaging type. The infrared image is projected by mirror optics on a thin membrane of infrared-absorbing material, producing a temperature pattern, which can then be converted and scanned (like a television camera tube) to obtain a visible image.

Progress in infrared imaging systems is mostly dependent upon developments in the infrared-sensitive membrane or "retina." For example, the membrane must be extremely thin to prevent lateral heat conduction and consequent deterioration of the temperature pattern.

One approach uses an ultra-thin membrane developed by research scientists for supporting infrared-sensitive material. The supporting membrane is about a millionth of an inch thick. It was made by taking anodized aluminum foil and chemically dissolving the aluminum metal, saving only the thin coating of aluminum "rust" that coats the foil.

This approach was used in a thermal-imaging tube called the *phothermionic image converter*. Basically, the system works something as follows: The front of the membrane is coated with an infrared absorbing material, and the back of the membrane is coated with a photoemitting material. The photoemitting material is temperature sensitive, so that the infrared image becomes an "image of photoemission" for the membrane. As the infrared image is optically projected on the membrane, the membrane is simultaneously scanned with a light spot. The photoelectric current produced in the photoemitting material by the light spot is modulated by the infrared "temperature" image, so that the photoelectric current can be used to reproduce the infrared image of a stationary or moving scene on a television screen.

New principles and methods of infrared imaging are presently being developed at the research laboratories. ■

## LAMPS AND LIGHTING

### more lumens, more improvements

Fluorescent lamps have become such an accepted part of general lighting and change so little in outward appearance that improvements are often overlooked. As one example, during 1959, engineers achieved nearly as much improvement in lumen output as they had in the previous five years. The big improvement was made possible by better control of phosphors, utilizing the particle size that improves the efficiency of conversion of ultraviolet to visible light, while re-

ducing absorption and reflection. In essence, this means maintaining a phosphor mixture with a small percentage of very fine or very coarse particles.

Appearance is an important factor in some lamp applications. Last year, engineers developed a white translucent end base for fluorescent lamps, which can be used in place of the standard black base lamp. However, the process was not as simple as the words sound. The base and the cement to hold it in place had to be dimensionally stable and not be affected by heat or humidity. Also a new method of attaching the base to the lamp had to be found to maintain the translucent feature. The answers were found in the form of a urea plastic and in a method of cementing the base to the inside surface of the lamp rather than to the outside, as has been customary.

Lamp engineers have always been faced with a choice of quite different characteristics when selecting either fluorescent or incandescent lamps for a given application. Incandescent lamps provide a concentrated source of light, with high brightness. Fluorescent lamps, on the other hand, have low brightness, but concentration of light is difficult. A new experimental lamp may enable concentration of light from fluorescent lamps, but with lower surface brightness than incandescent lamps.

This is the so-called labyrinth lamp, which, in effect, forces the arc of a fluorescent lamp to follow a zig-zag path across a flat, square, and relatively thin lamp. An experimental model is about 9 inches square and a little over an inch thick. In the lamp, the arc follows a winding path about 54 inches in total length.

The labyrinth principle has been tried before by lamp engineers, but was not practical because pressed glass had to be used, and it was too thick and too expensive for production purposes. Recently, blown glass has become available in this form, which now makes such a lamp practical. The new lamp is still in early development stages and many problems remain to be solved. However, the labyrinth lamp eventually may fill a need for a concentrated fluorescent lamp. ■

## lamps for photography

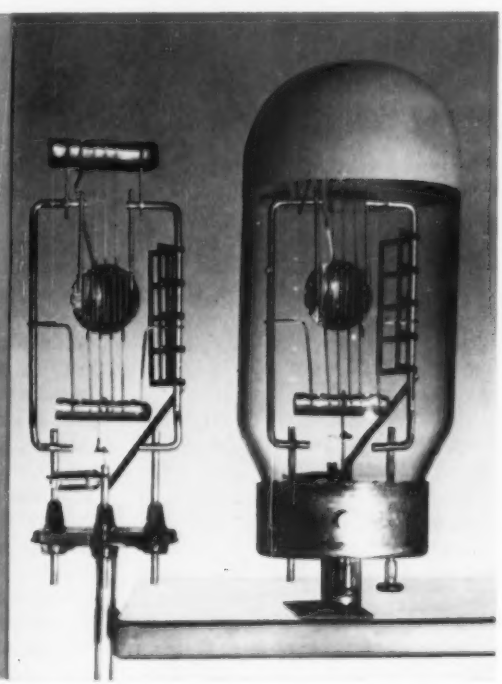
In both photography and projection of the processed film, the light from a lamp must be directed by some form of reflector. An increasing number of lamps for both photography and decorative lighting purposes have the reflectors built into the lamp itself, so that the light output of the lamp will not be subject to the many variables of external reflectors. Two unusual new lamps—one for projection and one for high-speed photography—have internal reflectors.

As the use of high-speed photography in industry increases, the requirements necessitate smaller and more portable light sources. Last year, engineers developed a new 300-watt reflector photoflood lamp that—in the most common type of application—gives more light output per unit area of light source than its 750-watt predecessor. High-speed photo lamps are usually burned at a distance of 10 to 16 inches from the subject; the new lamp has a narrower beam spread than the old bulb, and therefore less light is lost on surrounding areas. The smaller bulb size enables use of the lamp in confined areas, unlike the more cumbersome 750-watt unit.

The new photoflood lamp is made in two versions—a 115-volt lamp (DVP) for commercial and industrial photographers, and a 28-volt version (DXA) for use primarily in aircraft.

In projection lamps, a primary objective is to get as much screen brightness as possible from a given lamp. With a given lamp, this is largely a function of the reflector and the optical systems of the projector. A new projection lamp contains a small concave molybdenum mirror, positioned close to the concentrated filament coils, which leads to three improvements. First, it produces more screen brightness; second, it eliminates the need for an external reflector; and third, it reflects heat away from the rear bulb wall, thus reducing blackening of the rear wall and contributing to cooler lamp operation.

Some previous projection lamps have included a flat shield positioned close to the filament. However, the concave mirror system produces from 10 to 20 percent more screen brightness, the exact value depending upon the type of projector optical system. ■



**Left**—By increasing the plate voltage to 6000 volts, this television damping tube (Type 6CQ4) permits the use of higher picture tube anode voltages. Central to this development is the use of a glass button supporting and insulating structure between the anode and cathode. Previously, the plate voltage of this type tube was limited to 4500 volts, because arcs would develop between the anode and cathode through the layers of the conventional mica insulator.

**Right**—This new lamp for slide and movie projectors has its own reflector sealed in the bulb.

## high-frequency lighting moves ahead

High-frequency lighting, using a 1500-cycle lighting circuit instead of the normal 60 cycle, has several attractive

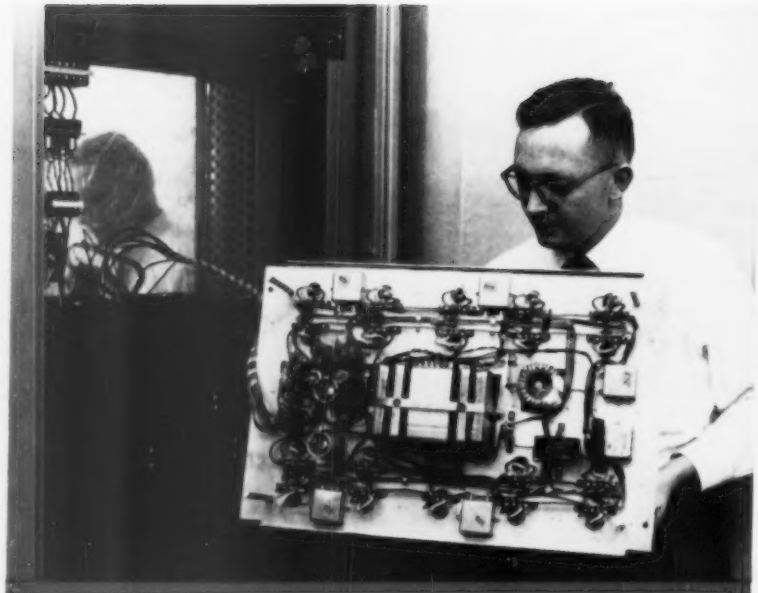
advantages. For one thing, fluorescent lamps are more efficient at higher frequencies. And, equally significant, the size and the power loss of ballasts are drastically reduced. To date, however, most high-frequency systems have required a rotating system for frequency conversion, located in a central vault, with long high-frequency cable runs (and thus high losses) to the lamps themselves.

During the last few years, however, high-frequency lighting has moved several steps closer to widespread application with the development of static converter systems, made feasible by the rapid development of new semiconductor devices. Several pilot installations of static high-frequency lighting systems have already been made by Westinghouse, and a complete building installation is scheduled to be completed in late 1959 or early 1960 at Hamilton, Ontario.

The three important elements of a static high-frequency system are the transistorized power converter, the ballast, and the distribution system itself. The system to be installed at Hamilton will have a bridge-type converter circuit operating from a full-wave rectifier using semiconductor diodes. It will be fed from a 208-volt, 60-cycle supply. The converter will supply three kw of load at 1500 cycles.

While the high-frequency lighting system has proved itself in several pilot installations already, widespread application is still a year or more away; however, more pilot installations undoubtedly will be made in the near future to verify newer designs.

The high-frequency lighting situation is firmly tied to semiconductor developments, which are moving at a rapid pace. For example, the recently developed Trinistor, a silicon controlled rectifier, may well prove more suitable than the present transistor and semiconductor-diode combination. Thus, while high-frequency lighting is practical today, engineers are looking forward to more effective and efficient systems using the newer components that will be available to them in the near future. ■



This pilot installation of a static high-frequency lighting system is operating in the Cleveland Engineering Society's Engineering and Scientific Center. The static converter panel, shown here, supplies 1500-cycle power to fluorescent fixtures.

## airport lights go underground

With the advent of high-speed jet aircraft, many new problems have been created for both military and civilian airports. Among these is the need for better lighting, to insure instant identification of the runway position and configuration for the pilot. Two new lights—a flashing condenser-discharge unit for approach lighting, and a steady burning light for use in both approach and runway lighting—indicate trends in airport lighting. Both are designed to be virtually flush with the airport surface; each unit projects but one inch above the runway.

*Condenser-Discharge Unit*—Flashing condenser-discharge lights have been an integral part of approach lighting systems for better than a decade. However, these have been large units mounted in an elevated position in the approach zone of the runway. The lights are arranged in a row, and flash in rapid sequence, directing the pilot toward the end of the runway.

However, to increase the safety margin for planes that land at high speeds, many airports have extended the paved area 1000 feet beyond the runway threshold, or well into the area normally occupied by approach lights. This has meant that some of the approach lights have been forced to go underground, to eliminate obstructions in this overrun area.

Several flush approach systems have evolved. One of the first consisted of a unit placed in an excavation in the runway, with the hole covered with an open top grid. This required heaters to melt ice and snow in the excavation, as well as a drainage system. Another solution separated the elevated unit into two parts, putting the lamp assembly in one excavation and the power supply in another. However, problems have developed because of the heat developed by the 50 watts required to operate the filaments of the rectifier tubes (the condenser-discharge lamps are dc units).

The new flush unit (Type CD-3a) combines the power supply and lamp assembly into one compact unit, 7¾ inches in diameter, and 11 inches deep, which projects but one inch above the runway surface. The compactness of the design was achieved by using a smaller tubular lamp in place of the helical shaped lamp of the elevated light, and by using silicon rectifiers instead of vacuum tubes. This also enabled the elimination of filament windings from the transformer, and made possible a further reduction in size. The lamp itself is mounted below the level of the runway, and light is directed toward the pilot by a prism in the top assembly of the light unit.

In a typical installation, seven flush units are combined with 21 elevated units. They are mounted 100 feet apart on the extended centerline of the runway, and are flashed in sequence. Each unit is flashed twice a second with a time interval between adjacent units of 1/60 of a second.

This unit was developed for the Air Force and is currently installed in five bases in this country.

*Runway and Approach Light* — A running mate for this new flashing light is the new runway light. In outward appearance, the installed units are identical, since the same cover assembly and prism unit is used in each. However, the runway light puts out a steady beam from a sealed-beam reflector lamp.

This new light is designed for use in various configurations of runway lighting, and since it is a flush unit, with the same one-inch projection of the flashing unit, it can be used in either approach lighting or runway lighting. Three different top assemblies have been designed to be used with different patterns of lighting. One uses the same top as the flashing unit, with one window for light output. This is used at the approach end of the runway as a steady burning guidance light for approaching aircraft. A second top has two windows, 180 degrees apart for mounting on the centerline of the runway, or in taxiways when fitted with blue filters. A third top assembly is used in the new narrow-gauge lighting system, in which lights are mounted in rows 60 feet on either side of the runway centerline. It also has two windows, but each is turned 3.5 degrees toward the runway centerline.

Both the condenser-discharge unit and the runway light are designed for simple installation and maintenance. The "can" containing the power supply can be installed in the concrete runway without regard to accurate alignment of the light beam. During installation, a ring on the top assembly can be easily adjusted to align the light beam along any desired path. Once aligned, it is clamped in place. When the top assembly is removed for maintenance, a staggered arrangement of bolts insures that it can be remounted only in the same position, so that no realignment of the light beam is necessary.

About 5000 of these new runway lights have been delivered to the Federal Aviation Agency. ■

## more light for classrooms

Recent lighting research studies have indicated that the recommended foot-candles of illumination for classrooms should be doubled for best visibility, and new standards have been established by the Illuminating Engineering Society. To lighting engineers, one of the difficulties is that glare becomes more of a problem as light output from luminaires is increased. And just to make the problem worse, the higher output lamps produce more heat, and therefore are normally used in open fixtures, where direct glare is at a maximum. The design of a new classroom luminaire overcomes these difficulties, and is appropriately called the Triumph.

The glare is reduced by a prismatic lens. Normally, some efficiency is lost through the use of a lens on such luminaires, but the new design is such that its photometric efficiency is as high as conventional louvered fixtures. The lens is concave, so that it is not an inherent "dirt catcher." To eliminate the heat problem, openings are left between the lens and the luminaire housing so that air can circulate freely through the unit.

The new luminaire is designed in 2- and 4-lamp units, for 4- or 8-foot lamps; all sizes use 425 or 800 milliampere rapid-start lamps. ■

This flush-mounted flashing light has power supply and lamp assembly in one compact unit.

# AVIATION

## erector-launcher for Atlas missile

Moving from the experimental to the operational stage of a product requires much engineering consideration, but this shift in emphasis is not nearly as complicated with an industrial device as with defense equipment, such as the launching and erection equipment for the Atlas missile.

The sight of a huge gantry tower swarming with technicians, engineers, and scientists is now a familiar one. But in operational use, the Atlas missile must be operated by soldiers in some isolated outpost—further, the missile must be readied quickly and without mishap.

Replacing the gantry tower is a simple erection boom, which lifts the missile from a carrier truck, raises it to the firing position, and swings back so the missile can be fired—in a matter of minutes. The boom is powered by a React-O-Verse drive, which runs on an elevated trolley; the trolley is connected to the boom so that as the trolley moves back, the missile is raised.

Obviously, many safety interlocks had to be incorporated in the control system to prevent damage to the missile, even when faced with a mechanical failure or a mistake on the operator's part. The problem is further compounded by the fact that the missile must be accelerated and decelerated smoothly to prevent undue strains in the missile structure.

In addition, though the missile presents a heavy load at the horizontal position, its changing center of gravity "carries it" after about the 60-degree mark. Thus the drive motor must operate part way as a motor and part way as a brake, and maintain constant speed.

These operational problems have been met with a combination of a Cypak control system and a React-O-Verse drive. The Cypak switching circuitry processes a myriad of information received from various limit

switches, valves, locks, and other remote devices. To illustrate the amount of automatic interlocking involved, by pressing a button, the circuitry automatically locks the boom clamp to the missile nose cone, raises the missile to the firing position, unlocks, opens, and retracts the nose clamp, locks the launcher support, unlocks the boom from the launcher, and swings the boom back away from the missile. In addition, the position of the missile is automatically indicated by lights in the control room.

By using a React-O-Verse control, consisting of a Magamp controlled saturable reactor control, and a 75-hp, type CW, wound-rotor motor, smooth acceleration and deceleration can be obtained, because the reactor scheme completely eliminates contactors.

The Cypak control and React-O-Verse drive are especially important in this application, because effects of dust, humidity, and other environmental conditions do not hamper the operation of static components.

The system was designed in collaboration with the erector boom designer-builder, Goodyear Aircraft, and the prime contractor for the Air Force, Convair (Astronautics) Division of the General Dynamics Corporation. ■

Shown in operation is the Atlas missile erector, which can raise a missile from a horizontal to a vertical firing position in a matter of minutes.

## aircraft electrical systems

In principle, most of the functions performed by aircraft electrical systems have counterparts in systems designed for use on land. But there the similarity ends. The requirements for airborne systems often require totally new approaches and the use of quite different techniques.

The trend to static devices for aircraft systems tends to be a major factor in design. An example is a constant-frequency power supply, which uses static semiconductor switching devices. The Freqconstat system consists of a variable speed ac generator and associated voltage regulator, and a static frequency converter. Variable frequency from the generator is converted to constant frequency voltage through a static switching system. The generator output phase voltages are switched in sequence for a given time interval to each phase of the load. Each phase of the load receives its power from the converter by sampling first one phase voltage, then the next, and so on. The system frequency is equal to the difference between generator frequency and switching frequency.

The new system thus provides precise frequency control independent of input speed. Reliability is improved compared to other systems by using a limited number of moving parts.

The unit is now in the development stage but ratings up to 60 kva are being designed. Larger systems will be available as larger ratings of semiconductor devices are developed.

Another example of the use of static devices is a new 100-ampere dc power supply. Basically, this is a transformer-rectifier unit, certainly not an unfamiliar component. However, for aircraft use, weight, space, and reliability are at a premium. Thus, mechanical design becomes an extremely important factor. Here are some features: The transformer of the new power supply has coils of aluminum foil, which reduces the transformer weight by 15 to 20 percent for equivalent performance. With further development, the maximum operating temperature can also be increased over present limits with conventional wire-wound design. The physical construction of the transformer-rectifier unit places all heat-producing units as near to outside radiating surfaces as possible for efficient cooling. The power transformers are the feet of the unit and the heat sinks double as the walls.

Westinghouse developments utilizing these techniques will provide rat-

ings from 50 to 200 amperes for both low- and high-altitude applications.

A third new conversion system is a static inverter for aircraft applications. This is a 3-kva unit that converts 28 volts dc power to three-phase, 200-volt, 400-cycle power. The static inverter will replace rotary inverters of large power ratings and will be lighter, environment-free, and have longer life. Units from 100 to 3000 watts are currently developed. ■

## 480-kva—airborne

A new Westinghouse aircraft system will pack more electrical power into an airplane than any other system known. In fact, the first application, on the Boeing B-52H, provides three times as much power as the present system.

This system is rated 480 kva, applying four 120-kva ac generators operated in parallel. Each generator is rated 120/208 volts, 3 phase, 400 cycles, at 8000 rpm. Each system, as installed on the B-52H, includes in addition to the ac generators, transistorized voltage regulators and control panels, current control and current transformer packages, differential current transformers, and circuit breakers. The system will provide voltage regulation of plus or minus 1.5 percent from zero to 100 percent load, will have an overload capacity of 150 percent for five minutes and 200 percent for five seconds.

These generators are a part of a complete line of generators rated 10 kva through 120 kva, the design of which was originally developed several years ago.

Three silicon diode rectifiers are mounted in the generator shaft and replace the functions of the commutator, slip rings, and brushes. The unit also includes an integral high-frequency permanent magnet generator to provide control power for the system.

The generator weighs but 155 pounds and is approximately 11 inches in diameter and 14 inches long. It weighs but 1.25 pounds per kva, compared to 2 pounds per kva for the previous B-52 generator, rated 40 kva. ■

## improvements in airborne radar

The parametric amplifier, a relatively new device in the electronics field, is being considered for a number of airborne radar and communication applications. The fundamental advantage of this amplifying device is its extremely low internal noise characteristic. Hence, by adding a parametric amplifier on the front end of a radar receiver, or any receiving system, the device will sense extremely small signals since internal noise is the ultimate limitation on the minimum signal that can be amplified. Depending upon the applications, radar ranges can be increased from 30 to 60 percent; in communications systems, the range can be at least doubled. The increase in range has been found to be effective up to a point where external noise becomes the limitation.

The key element in the parametric amplifier is a variable-reactance semiconductor, called a parametric diode, which, when employed in a suitable network (usually microwave), will achieve amplification. However, to do this, a unique power source, called a "pumping" source, is required to supply the so-called pumping signal to the network—at a frequency two or more times the frequency of the signal to be amplified. The pumping signal changes the reactance of the parametric diode at the pumping frequency. The higher the pumping frequency with respect to the amplified signal, the truer the amplification characteristic. When the incoming signal is applied to the diode, the changing reactance achieves signal amplification.

*Pulse Doppler*—A radar detection tracking system being developed by radar engineers presents a unique combination of radar and digital techniques. This track-while-scan system simultaneously tracks several objects while continuously scanning. A high-speed digital data processor keeps track of multiple target information and displays the tactical situation. The radar system employs pulse doppler techniques; by use of the doppler shift—the apparent change in frequency of the reflected signal caused by relative motion of the transmitter and the target—reflections from stationary ground objects (ground clutter) can be rejected. This is particularly desirable in detecting and tracking low-altitude targets.

The airborne digital data processor, which sorts out the radar signals, is an all-static device employing silicon transistors. The device has the capability of 166 000 additions per second. The processor employs three basic components, an operand memory, an instruction storage, and an arithmetic and control unit. Each of these components is about the size of a suitcase. Although the first application is the automatic track-while-scan system, the processor is a general-purpose device, which can be used in any airborne application where its speed, capacity, and accuracy is required. ■

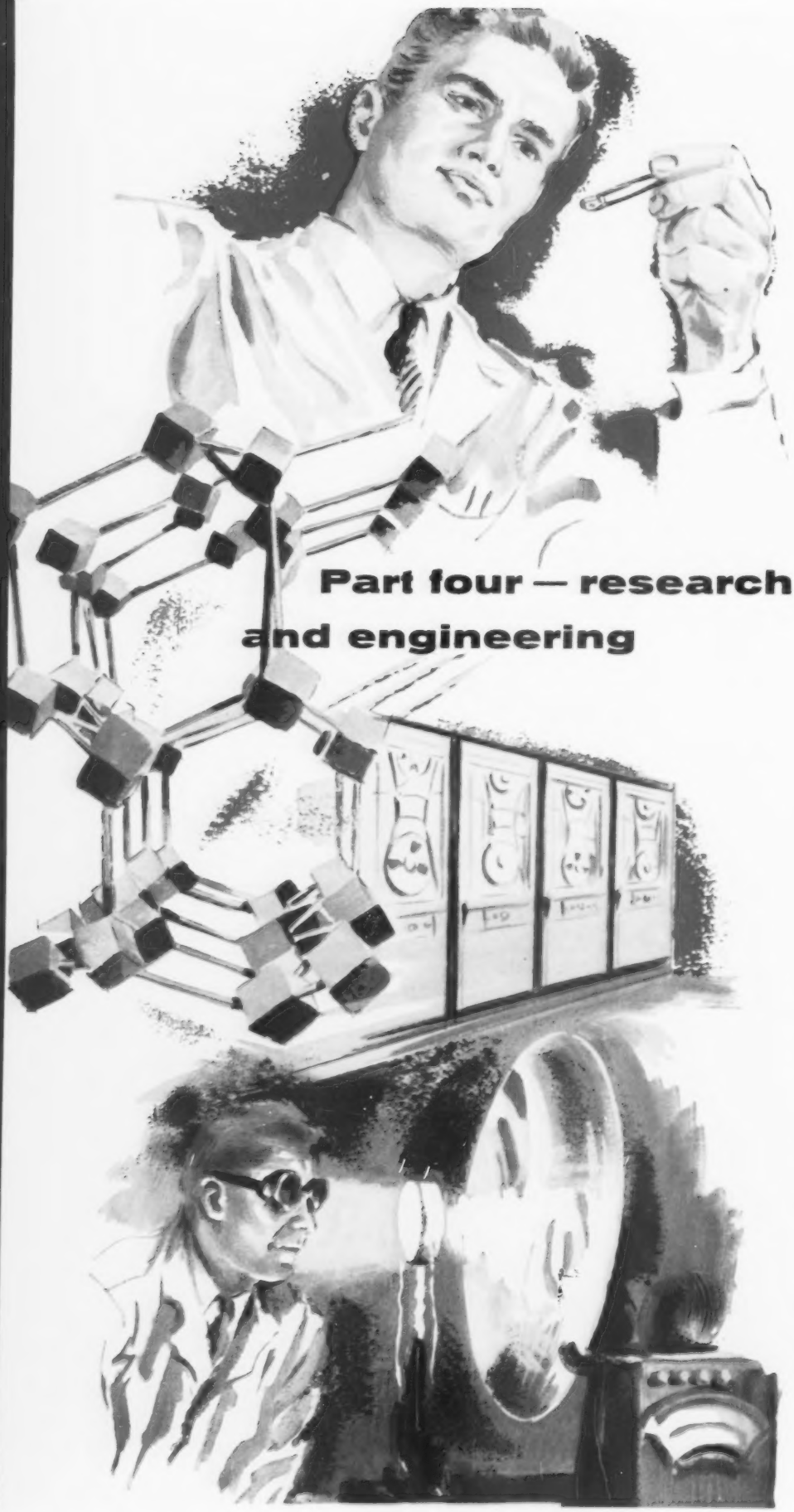
## capacitors for hot-shot tunnel

The hot-shot tunnel is becoming a popular device for testing scale-model aircraft. In this relatively inexpensive tunnel, air is heated in a chamber by an electric discharge and then released into the test section. The heat and speed of the air flow over the model approximate the conditions encountered in actual supersonic flight.

In one of the more common types of hot-shot tunnels, capacitors supply energy for the arc. Essentially, the greater the capacitance of the system and the higher the voltage, the greater the energy released in the arc and therefore the faster and hotter the air flow over the test model.

In a relatively large capacitor discharge tunnel to be built for the McDonnell Aircraft Corporation in St. Louis, Missouri, 2320 capacitors will be used to supply an arc of 4-million amperes at 12 000 volts. Air speeds from Mach 11 to Mach 24 will be produced in a test section whose diameter varies from 30 to 50 inches. Though the theory of a capacitor discharge is relatively simple, a tunnel of this capacity presents many complex problems. For instance, to obtain a discharge time of only 1 to 3 milliseconds, coaxial cables have to be used throughout—including the electrodes themselves—to reduce inductance to a minimum. The inductance has been reduced to 1.04 microhenrys including capacitors, cables, and the electrode itself. In addition, the total ac resistance of the system is only 115 micro-ohms.

However, a discharge of 4-million amperes is no small current, and the coaxial conductors to the electrode had to be designed to withstand tremendous pressures and forces. For instance, the conductors are reduced in diameter as they approach the electrode. The force tending to push the inner conductor out of the outer tube is about one million pounds. ■



# Part four — research and engineering

## more computer capacity for design

The design of nuclear reactors has come a long way since the days when nearly every major nuclear question had to be answered experimentally. Those days have not yet disappeared by a long shot, but the fund of knowledge and experience built up over the past ten years, plus the increasing use of large digital computers, is gradually changing reactor design from an art to a science. In order to achieve substantial performance improvement in reactors, nuclear design is now entering a phase where the operation of a core must be worked out completely on paper before it is built.

A new addition planned for the Bettis Laboratory is a Philco Transac S-2000 computer, which will hasten the day when reactors can be designed completely by computer. The Transac is a transistorized computer that is about five times as fast as previous Bettis computer facilities; it also has other important advantages.

The much higher computation speed, which is achieved at a relatively modest increase in computer cost, improves computation economy very substantially, making economically feasible much larger calculations than could be afforded on the earlier computer. In addition to the speed advantage, the Transac and other new computers have a basic improvement known as "buffering," which permits the machine to move, concurrently with computation, data and instructions between internal magnetic core memory and much larger auxiliary (at present, magnetic tape) data storage facilities. Thus, the total volume of information that can be processed without interrupting computation is not limited to the 32 000 word internal capacity, but is approximately a thousand times larger. The machine's ability to move data during computation, while it permits very large problems to be handled efficiently, requires careful coordination of the various parts of the problem, since all data and instructions must be in the right place at the right time.

These features of increased speed of calculation, buffered operation, and economy permit an increase of a factor of over ten in the number of points describing the reactor, and thus the accuracy of design is substantially in-

creased. The new computer will permit a significant amount of nuclear design calculation work to be performed in three space dimensions, whereas the limitations of the earlier computer permitted little beyond exploratory work in three dimensions. ■

## EL still on the move

One critical factor in any lamp designed for general lighting is maintenance, which to lamp engineers means the length of time the lamp will operate before its light output drops to a predetermined percentage of its initial value. In this respect, research engineers took a big step during 1959. By making changes in the chemical composition and the preparation methods of the basic zinc sulphide phosphors, they have increased their operating lifetime many fold—for all colors. Based on experiments recently conducted, the half life—operating time to half the initial brightness—has been increased over 30 times for electroluminescent lamps.

A further improvement in half life was gained through improvement in materials and design of protective coatings applied to the lamps. These improved coatings also extended the operating temperature limits to minus 54 degrees C and plus 71 degrees C, and also increased the resistance of the lamps to high relative humidity.

As part of this same development, engineers have discovered a procedure that will hasten experimental work on electroluminescent lamps. Because of the inherent long life of electroluminescent lamps, determination of their maintenance characteristics can be a time-consuming process. This is particularly true at low frequencies where the lifetime of phosphors is longest. Last year, research engineers observed that by proper mathematical correlation, the results of high-frequency tests could be used to determine low-frequency lifetime. Thus an accelerated lifetime test can now be conducted at high frequencies and the results interpreted to approximate 60 cycle performance. For example, to test one electroluminescent lamp at 60 cycles, about 30 days would be required before the lamp output dropped to half its initial brightness; using accelerated testing procedures, the same test can be conducted in 8 hours.

The uses for electroluminescence for other than general lighting are increasing, and each development contributes to the general knowledge of the phenomenon. In one study being conducted by research engineers, the brightness of one portion of an electroluminescent display panel must be, at a given instant, brighter than similar surrounding areas, and the contrast must be sufficient to permit quick visual discrimination. The need here is for an electroluminescent phosphor whose brightness increases rapidly with voltage, so that, say, if one area is operating at twice the voltage of the surrounding areas, its brightness will be about 50 times as great. In comparison, the brightness of an ordinary electroluminescent phosphor may increase by only 15 times under the same operating conditions.

This type of characteristic is most easily obtained by control of the phosphor particle size such that small particles, which give a high slope to the brightness versus voltage curve, are used. However, the problem is how to obtain a high percentage of small particles in a phosphor. Any kind of "sorting" process is almost hopeless from a practical standpoint. The answer was found in revised processing methods, which led to control of particle size. The new high discrimination ratio electroluminescent phosphor is being used in a display device in conjunction with light amplifier and photoconductive cells.

Another development program has produced a deep red emitting phosphor that can operate at lower frequencies than previous red phosphors. This phosphor is part of a new electroluminescent system capable of emission in any color from blue to deep red through variation of the composition. Of equal significance is the fact that this is the first known electroluminescent phosphor whose emission extends into the infrared region; this leads to the possibility of ultimately producing a phosphor that can emit entirely in the infrared region. ■

## molecular electronics

Atomic charges, fields, and spins have become the building blocks for a new form of electronic system—the so-called *molecular circuit*. Actually, molecular circuitry is not a conventional form of "circuitry" (an array of individual components, arranged and wired together in some ordered fashion); instead, arrangements of the atomic distribution of material are used to perform such functions as energy conversion, amplification, detection, and frequency selection.

A completely new approach is required for designing the molecular system. Rather than design a combination of circuit functions, the complete system must be considered as a means for transforming energy. Scientists use their knowledge of the structure of matter to design an arrangement of materials that will accomplish the desired system energy transformation. The molecular system is then synthesized, possibly into a single crystal of material, by such techniques as growing, etching, diffusion, and alloying. The result is a compact block of material, which, with a given energy input, will produce the desired form of energy output.

To develop a molecular system, the starting point may be a block of material made of a single crystal, where the atoms are packed in nearly perfect order. Controlled impurities are then introduced into the crystal.

A real boost to the molecular electronic system engineering concept came when Westinghouse research scientists developed a method for growing germanium crystals in the form of long, thin, uniformly flat ribbons, ready for application. These dendritic germanium ribbons (from *dendrite*, a tree-like crystal formed during solidification) provide the crystal base with which to start building a molecular system. Scientists hope that this dendritic germanium ribbon, the first major breakthrough in the preparation of semiconductors in 10 years, may provide the "chassis" for the molecular "circuit" of the future.

Westinghouse is presently carrying out further research under a development contract issued by ARDC's Wright Air Development Center, as a part of ARDC's broad effort in the field of molecular engineering.

The first step in the ARDC-Westinghouse program is the examination of total systems to evaluate necessary basic functions, and the development of molecular electronic blocks for accomplishing these functions. Obviously, the goal is to combine the maximum number of functions into the minimum number of blocks.

These blocks will duplicate functions already widely used in conventional electronic circuits. For example, amplifiers that correspond to conventional multi-stage amplifiers, tuned amplifiers, and logic circuits have been developed in monolithic block form. Transducers that provide pulse shape, position, and frequency modulation have also been built.

At present, most of the major functional blocks required for the contemplated military systems have been invented and their feasibility proven. The next important step is the expansion of this basic catalog of molecular functions so that variations of these functional blocks can be made for a number of systems. For example, amplifiers must be designed for a range of power levels, gains, impedance levels, etc.

Scientists feel that they are presently at the point in developing molecular systems where conventional circuit designers were when the feasibility of the vacuum tube had been proven. Now, they must develop and integrate a number of variations in these basic molecular subsystems to form total molectronic systems. ■

## thermoelectricity

The feasibility of thermoelectricity as a means of generating useful amounts of electric power is no longer questionable. Nor is there any doubt about the feasibility of the same principle for cooling or refrigeration purposes. The problems remaining are largely wrapped up in the development of better materials and the engineering of devices—and the manner in which these are solved may well determine whether thermoelectricity will have general or only specialized application. In 1959, substantial progress was made on both fronts.

*Materials Advances*—Materials are perhaps the knottiest problem. As scientists now view the situation, no one material is likely to have satisfactory thermoelectric properties over the range of temperatures for power generation and refrigeration.

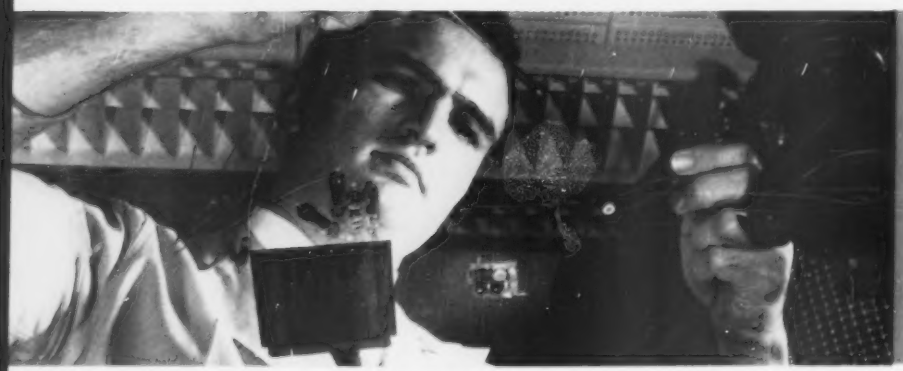
Present thermoelectric materials fall into three general categories: semiconductors, metallic compositions, and mixed-valence compounds. Semiconductor materials have the best inherent properties, including the ability to generate a reasonable electric voltage, low electrical resistance, and low heat conductivity. Certain mixed-valence compounds, on the other hand, are capable of operating at much higher temperatures, which is a necessity for some power applications. Unless an "ideal" material is found, the best possibilities seem to derive from "cascading" materials of different temperature limitations, so that waste heat from one stage would be used by the next. Using such techniques, scientists foresee efficiencies as high as 35 percent from power generators.

A new thermoelectric material developed during 1959 helps bridge the gap between known semiconductor materials and the high-temperature mixed-valence compounds. This new material, a semiconductor, is a three-element chemical compound known as indium arsenide phosphide. It is the most efficient thermoelectric semiconductor material yet discovered for the operating range of 850 to 1500 degrees F. The most significant fact is that the efficient operating range of a semiconductor material has been increased to 1500 degrees, where previous semiconductors did not perform well. Thus the temperature range of semiconductor materials has been extended to the point where mixed valence compounds can take over.

*Thermoelectric Devices*—In mid-1959, the Air Force unveiled a thermoelectric generator believed to be the most powerful built to date. The new generator, known as TAP-100 (terrestrial auxiliary power), produces 100 watts of electric power. The TAP-100 is about the size of a medicine ball and weighs 40 pounds. It delivers three times as much power per pound of weight as any previously announced generator. The unit operates at a temperature of 850 degrees F, and can operate directly from a propane gas flame; with modifications it could also operate with gasoline or kerosene.

Meanwhile, scientists and engineers were at work on an even larger generator for the Navy. A contract awarded to Westinghouse called for the design and construction of a 5000-watt thermoelectric generator; the generator is intended to be a small-scale prototype of a shipboard installation, but may be used as a portable power source. As planned, the thermoelectric unit would have its low-temperature junction cooled by water, preferably ordinary sea water. The unit will be designed to operate existing Navy electrical equipment, and will be designed for maximum shock and vibration resistance.

Another thermoelectric device to be built for the Navy will be an experimental unit that combines into one system a thermoelectric air conditioner, space heater, and a refrigerator freezer. The Navy will use the experimental system to test the suitability of



thermoelectricity for air conditioning and refrigeration on ships.

The design of the model will be such that it lends itself to construction of a full-scale system. The three components will be built of identical thermoelectric modules, which can be individually removed or replaced and can act as building blocks for a system of larger size.

The air conditioning portion of the system will have a one-ton capacity, and will supply chilled water to a standard Navy unit space cooler. The thermoelectric heater will supply heated water to a standard Navy unit space heater. The two cubic foot refrigerator-freezer will be capable of maintaining a temperature of zero degrees F continuously. ■

## solid-state electronic tubes?

During the past decade, solid-state semiconductor devices have taken over many of the functions previously performed by electronic tubes. Recent discoveries may make possible a marriage of the two devices—in the form of a "solid-state electronic tube."

The idea is based on the fact that physicists have discovered how to obtain a constant flow of electrons from the surface of certain semiconductor materials. Last year, Westinghouse scientists discovered this effect in silicon carbide, and, importantly, the density of electron flow is equal to that in the average electron tube.

The escape of electrons from silicon carbide accompanies the emission of visible light from the crystal. The visible light is a form of electroluminescence, and occurs when enough voltage is applied across a junction to cause breakdown. When breakdown occurs, small blue spots of light appear in the semiconductor crystal near the junction. Electrons escape from these spots, especially those nearest the surface of the crystal. The spots are small—about 50 millionths of an inch in diameter. Currents from these spots up to one millionth of an ampere have been measured, a density comparable to that of a typical vacuum tube.

Using this principle, it is possible that an electronic tube can be built, in which the heated cathode is replaced by a small semiconductor crystal. The crystal, unlike the conventional cathode, would require a small amount of power and would yield electrons instantly and indefinitely when a small voltage was applied across it.

The fact that an adequate flow of electrons can be obtained from a pinpoint source could lead to many advantages in the construction of complicated tubes. It would simplify focusing of the electron beam, and eliminate many of the elements now used for this purpose.

Scientists are now doing further research on the electron emission from silicon carbide, with the eventual aim of making use of this phenomenon in working devices. ■

## a new look at lightning

Five years ago, electric utility transmission engineers felt that they could predict the electrical performance of transmission lines with respect to lightning effects with a fair degree of accuracy. Conventional methods of calculation had widespread acceptance and had proved satisfactory in countless cases. However, the unusual number of transmission line flash-overs that occurred in service on the new 345-kv lines, as compared to the performance predicted, has caused the utility industry to take a new look at lightning. The only characteristics of the new high-voltage lines different from previous high-voltage transmission lines appear to be their greater height and a single ground wire.

Westinghouse engineers are presently studying two fundamental aspects of the lightning problem: First, a further development of the theory of the lightning stroke itself. The second phase of the problem, which is being developed simultaneously, is to determine better methods for using the stroke characteristics, once they are determined, for calculating the effect of lightning on the transmission line. In the last two years, progress has been made in both phases of the problem.

In the past, the lightning stroke has always been considered to have a wave front coming to crest in about four microseconds. However, evidence gathered in recent years indicates a much sharper wave front. A completely new concept—the Griscom Prestrike Theory developed by Westinghouse engineers—predicts two separate components to a lightning stroke. The first component, the prestrike, would be a sharp spike, rising to crest in a fraction of a microsecond; this spike is followed by a conventional return stroke, which is predicted to take five to ten microseconds to crest.

To check this theory, a measuring device was needed that could detect these early fractional microsecond fronts of the voltage wave. Consequently, a kine-klydonograph has been developed, a device that can measure wave-front voltages within the range

**Left**—The improvements made possible by the molecular approach are demonstrated by a light-sensing device for a satellite telemetry subsystem. Shown are the components required for the subsystem employing conventional circuitry (*left*), transistorized circuitry (*middle*), and a molecular electronic element (*right*).
**Center**—This thermoelectric generator produces 100 watts of electric power.
**Right**—This experimental electronic tube gets its supply of electrons from a tiny crystal of silicon carbide no larger than the head of a pin. The silicon carbide crystal is inside the cartridge being inserted into the tube.

The kine-klydonograph can measure lightning wave front voltages within the range of 0.5 to 10 microseconds.

of 0.5 to 10 microseconds. With measurements from this device, engineers hope to prove the prestrike theory.

During the 1959 lightning season, 23 kine-klydonograph units were installed. But unfortunately, for measuring purposes, the 1959 season turned out to be an extremely calm one. Only one stroke was measured. The measurement indicated that the kine-klydonograph is functioning in the expected manner; furthermore, the evidence is encouraging in that it does preliminarily indicate the presence of a prestrike. However, engineers are quick to point out that a number of measurements are required so that a statistical analysis can be made, before the characteristics of the lightning stroke can be defined. With a more active lightning season in 1960, engineers hope to develop the physical data that will define the stroke characteristics, needed for the second phase of the lightning study.

In the second area, Westinghouse engineers working with the effect of lightning strokes on transmission lines are also developing new theory from that used in the past. While much too complicated for explanation here, the new calculations are based upon electric field theory—the dynamic motion of a set of magnetic fields, in which electromagnetic potentials are represented. This approach will obviate the previously questionable concept of representing transmission towers either by inductances or surge impedances. Another major difference between the new method of analysis and previous theory is the addition of the simultaneous effect of charge in the lightning stroke channel above the tower to the usual calculation of the effect of lightning current injected into the tower top.■

## total utility system planning

The spectacular growth projected for electric utility loads during the next 10 to 20 years presents a formidable planning problem to utility engineers. In 10 years, it is estimated that generating capacity will reach 295 000 000 kilowatts—more than twice today's capacity. In 20 years, it is estimated that the installed capacity in the United States would be sufficient to serve the entire world today.

The complex problems that will be created by this tremendous load growth can be met only by careful long-range planning methods. Consideration must be given to such factors as: installation dates for new generation capacity; the type of generating unit—coal, hydro, or nuclear; size of generator units; use of new sites or existing sites; and transmission routes and voltages.

These are some of the questions that are being considered by a coordinated team made up of engineers from the Public Service Electric and Gas Company of New Jersey and Westinghouse. This group of engineers is making intensive studies of load forecasts, risk of shortage, transmission plans, production costs, capital costs, and present-worth economics for the Public Service system. This information has been used to create and operate a complete mathematical model of the Public Service system, and adjoining interconnections.

To operate the mathematical model, a large array of variables, both predictable and unpredictable, must be considered. For example, forced outages as well as scheduled and economy outages must be accounted for. To produce simulated forced outages in the mathematical model, probability distributions were developed from system historical records. Use of Monte Carlo techniques with these probability distributions simulate forced outages for use in the mathematical system model. A similar technique is used to simulate system load growth in the model.

Operating rules and data are included in the model to simulate scheduled maintenance, periodic overhauls, and other operations under human control. Management reaction to low reserve capacity is another factor represented in the system model.

The mathematical system model is set up on a high-speed digital computer, which can reproduce 20 years of simulated system experience in less than 20 minutes. The model determines on a day-by-day basis what units will operate to supply the required load: it starts up these units, accepts forced outages, and operates the system. The model uses the same logic to make decisions as would be used by system planners and operators.

At the end of the 20-year simulation, the computer records all decisions made—dates when generation additions should be made, present worth of all expenditures, total capital needs, and production and operating costs.

Since Monte Carlo techniques are used to simulate future events, each rerun of the 20-year period will represent different possible sequences of events; however, each game is based on a statistical probability of conditions that the system could experience. Hence, by running a number of games, a statistical spread of the probable generator installation dates required to meet future loads is obtained. Other expansion problems, such as transmission line building, can be similarly evaluated.

This operational gaming technique can become a powerful aid to system planning, providing management with a new tool for economic evaluation of alternate expansion plans for the system. By surveying a large number of possible expansion programs, together with the weighted probabilities associated with each plan, management will be in a better position to evaluate long-range expansion plans. And once the overall program is adopted, each addition to the system can be coordinated with the overall plan. ■

# ENGINEERING HIGHLIGHTS ADDENDA

### [illegible] gets a new job

The decorative Micarta laminate used for many years as wall paneling in homes and offices now has a completely new function. It is now a radiant heating panel as well as a durable and attractive wall panel. This is accomplished by embedding heating elements in the panel by a new manufacturing technique.

In addition to the panel, a Micarta radiant heating baseboard has also been developed. The two heating devices are still in the experimental stage, but tests show that the panel operates at 80 to 100 degrees F and the baseboard at 130 to 140 degrees F surface temperature. ■

### [illegible]-panel picture tube

Dust particles will be frustrated in their attempts to get between the picture tube and safety plate of a new 23-inch tube, because these surfaces will be bonded together with an epoxy resin.

Two reflecting surfaces have been eliminated (the outer surface of the picture tube and the inner surface of the safety plate), reducing irritating reflections. Optical viewing area of the tube has been increased by 20 square inches, compared to the conventional 21-inch tube, by making the face of the tube almost rectangular. ■

### Vibragyro instrument

A prototype model of the Vibragyro, an angular velocity sensing instrument, is undergoing evaluation tests. The Vibragyro consists essentially of two vibrating masses operating in a translational direction at the same frequency but 180 degrees out of phase. When the assembly is subjected to an angular velocity about its input axis, a signal can be obtained similar to that from the conventional gyroscope. The device has several promising features: There are no moving parts making frictional contact, since the Vibragyro employs an electromagnetic drive and the masses vibrate by the flexing of spring members. The device also needs less driving power—as little as 1/100 of the conventional gyro—and starts faster with no delay for building up momentum. ■

### See-Matic circuit board

Trouble tracing on printed circuits has been simplified by a See-Matic circuit board developed by television designers. All components are identified on the bottom of the board with a special nonconductive paint. Tube pins are shown by code letters rather than numbers; the value of each component—resistor, choke, or capacitor—is given; controls are shown and values indicated. ■

### Infrared [illegible]

Development engineers have devised an infrared technique for determining current distribution in complex electrical conductor shapes. Infrared film is used, which responds to areas of localized heating, which in turn are produced by high current densities. Though the technique is in development stages, it appears to be a potentially powerful tool for determining current distribution too complex or time consuming for analytical methods. ■

### Hall multiplier for many applications

We have mentioned elsewhere in this issue the use of the Hall multiplier in a wattmeter (p 13). The heart of this watt-measuring device is a small electromagnetic structure with a Hall crystal embedded in the structure's air gap. By proper connection of the voltage and current input to this device, an output is obtained that is proportional to the product of the in-phase components of applied current and voltage. Such a device therefore has a number of other possible applications. Some examples are: an analog multiplier for computer applications, a phase detector, a function generator, and a modulator or demodulator, to name a few. With this in mind, instrument engineers have mounted the Hall multiplier on a vacuum-tube base for use as an electronic component. The device is now in a package ready for immediate use by the circuit designer. ■

### [illegible] surge study

Two mobile laboratories are presently being equipped with high-speed cathode-ray oscillograph recording equipment. These mobile laboratories will be used to investigate switching surges on power systems, at transmission voltages up to and including 345 kv. The purpose of the study will be to determine more thoroughly the nature of switching surges caused by faults, line dropping, and disconnect-switch operation. Switching-surge overvoltages are an important consideration as insulation levels of station equipment are reduced. The study will be carried on jointly with the American Electric Power System over the next two years. ■

### "tip-off" safety switch

The contacts of a new safety switch open when the switch is tipped more than 45 degrees from vertical. The switch is designed for use in portable room heaters and other portable electrical appliances that are electrical or fire hazards when accidentally tipped over.

The actuator of the tip-off switch contacts is a pivoted, steel pendant that tends to maintain a vertical position at all times, regardless of the position of the switch. For example, when the appliance in which the switch is mounted is upright, the pendant hangs vertically and the switch contacts are closed; should the appliance be accidentally tipped over, the pendant still hangs vertically but the switch contacts are opened. The switch is rated at 15 amps, 118 volts, or 8 amps, 236 volts. ■

### Faster cars for Philly

By replacing their old transit cars with light-weight, high-speed units, the Philadelphia Transportation Company is shaving 19 minutes and 57 seconds from the round trip between Bridge and 69th Street. In addition, they save a total of 45 cars. The reason for this improvement is that modern traction equipment can rapidly accelerate the cars to top speed due to the higher horsepower per ton of weight ratio.

Aiding improvement in performance is the use of computer analysis, which allows engineers to simulate the performance of equipment from station to station. Previously, engineers took several average station-to-station runs and used these as a basis for applying equipment. But with the computer, the acceleration, top speed, and deceleration of each run can be used to analyze proposed equipment. For instance, performance with different combinations of motors, gear ratios, and car weights can be simulated and the results of each evaluated with respect to the number of cars needed, the time required for a complete trip and overall economy. ■

### [illegible]-load indicator

A more accurate indication of load on an induction motor can be obtained by a panel instrument that measures the work component of load current (I cos $\theta$). Conventional ac ammeters measure total current magnitude without respect to power factor. Since induction motors operate at different power factors, dependent upon load, this new device gives a more accurate indication at light loads, without sacrificing full-load indication. The device is designed for use with a five-ampere current transformer, and can be used on either single- or three-phase, 50- or 60-cycle induction motors. ■

# TV TUBE WITH A MEMORY

As demonstrated by this photograph, a pick-up tube, called the Permachon tube, has been developed that can retain information on its target screen while being scanned. In this and other respects, this tube, which can operate in a standard vidicon camera, is more akin to a conventional camera than a tv tube. For instance, a scene can be stored on the target screen and continuously scanned and displayed for a period of thirty minutes. Interestingly, if the target is not scanned, the information will be lost.

The target of the tube can accurately retain information with exposure times as slight as 23 microseconds. In still another way, this unique tube is related to photographic film in that it can integrate optical information. When focused on a dimly lit subject, too dark for the naked eye to clearly recognize, the image builds up in brightness until it can be recognized on a television screen.

Unlike its celluloid cousin, the target screen can be erased with a flash of light and be ready for another picture in about one-fifth of a second. If this procedure is not followed, the tube will oblige by making double, triple, or if you like, infinite exposures.

Responsible for all these interesting features is a unique target composed of a semiconductor material, which was discovered during a materials research program. The semiconductor has the ability to store a conductivity pattern of an image and retain it while being scanned. The resolution of the semiconductor target equals about 600 tv lines with eight shades of gray—a quality which can be maintained for five minutes of scanning. When the image starts to degrade, it appears as a loss of contrast, with black areas turning to white rather than a loss of resolution.

WESTINGHOUSE